SOUTH CAROLINA

Bat Conservation Plan

South Carolina Department of Natural Resources

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BAT CONSERVATION PLAN

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This is the South Carolina Bat Conservation Plan. It has been revised and updated from the initial plan created in September 2015. This plan provides information on legal status, public health, conservation issues, natural history, habitat requirements, species-specific accounts, threats and conservation strategies for bat species known to occur in the state. The primary purpose of this plan is to summarize available information for these species and provide proactive strategies in order to help guide management and conservation efforts.

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Table of Contents

List of Figures

List of Tables

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Executive Summary

Purpose

This South Carolina bat conservation plan provides information on legal status, public health, conservation issues, natural history, habitat requirements, species-specific accounts, threats and conservation strategies for bat species known to occur in the state. The primary purpose of this plan is to summarize available information for these species and provide proactive strategies in order to help guide management and conservation efforts.

Bat Species in South Carolina

Of the 47 bat species documented in the United States (US), 14 are found in South Carolina. These include the big brown bat (*Eptesicus fuscus*), Brazilian free-tailed bat (*Tadarida brasiliensis*), eastern red bat (*Lasiurus borealis*), eastern small-footed bat (*Myotis leibii*), evening bat (Nycticeius humeralis), hoary bat (*Lasiurus cinereus*), little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), northern yellow bat (*Lasiurus intermedius*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), silver-haired bat (*Lasionycteris noctivagans*), southeastern bat (*Myotis austroriparius*), Seminole bat (*Lasiurus seminolus*), and tricolored bat (*Perimyotis subflavus*). Incidental records exist of the big free-tailed bat and the federally endangered Indiana bat. However, these species are not addressed in this document due to their rarity in the state.

All of South Carolina's bat species prey on insects and are of great economic importance to the state. Insectivorous bats are known to suppress nocturnal insect populations, including crop and forest pests, and greatly reduce the need for costly pesticides. The estimated annual value of bats in pest suppression services to South Carolina's agricultural industry is nearly $115 million, with the US agricultural industry estimate at $22.9 billion (Boyles et al. 2011). The beneficial ecological effects of bats can extend past insect consumption as they indirectly suppress pest-associated fungus and the toxic compounds they produce in corn (Maine and Boyles 2015), as well as reduce the substantial impact of pesticides on many other wildlife species (Pimentel 2009).

Status and Conservation

A total of twelve, or 86% of South Carolina's bat species, are on the list of South Carolina's "Species of Greatest Conservation Need" and considered "Highest Priority" in the South Carolina State Wildlife Action Plan or SWAP (SCDNR 2015). None of South Carolina's bats are listed as federally endangered, but the northern long-eared bat is listed as federally threatened. The eastern small-footed bat, Rafinesque's big-eared bat, and tricolored bat are all considered at-risk species by the USFWS. Rafinesque's big-eared bat is state endangered and the eastern small-footed bat is considered "species in need of management" or equivalent to state threatened. Currently, a USFWS petition is being addressed for the little brown bat (Kunz and Reichard 2010), and a status review is being conducted for the tricolored bat.

Conservation Issues

One of the most devastating threats to bat populations in North America is White-nose Syndrome (WNS). Mortality rates attributed to WNS have reached up to 90 and 100% at hibernacula, causing the death of between 5.7 to 6.7 million bats since it was first documented in New York during the winter of 2006/2007. A ten-fold decrease in the numbers of bats in North American hibernacula has been attributed to WNS, and significant local extinctions in many species have resulted, including up to 69% of former hibernacula of the federally threatened northern long-eared bat in North America.

Another significant, ongoing threat is the loss and degradation of important bat roosting and foraging habitat. From the time of European settlement until around 1970, 80% of bottomland hardwood forests in the Southeast were converted for agriculture purposes. Today, urbanization has been cited as the leading threat to southern forests, and may also decrease the functional value of forests through increased fragmentation, reduced water quality, reduced carbon storage, and increased complexity in the use of fire for forest management practices. Forestry practices can also have a significant effect on bats as the felling of trees and snags, building of roads, disruption of boulders in quarries, prescribed burns, and vegetation and insect control can result in direct mortality of bats. Other major threats include human disturbance, environmental contaminants, wind energy development, and unknown impacts of various agriculture and forest management practices as well as environmental changes associated with climate change.

Natural History and Habitat Requirements

All of South Carolina's bats use echolocation to identify and capture prey during flight or by gleaning insects from foliage, the surface of water, or on the ground. All of the *Myotis* species in the state, as well as the tricolored bat and Rafinesque's big-eared bat, are considered clutter-adapted species. Migratory bats are generally regarded as efficient flyers in open areas, and though many South Carolina bat species may have small seasonal movements, only the silver-haired bat is regarded as a true migrator. Other efficient open area flyers in South Carolina include the Brazilian free-tailed bat, hoary bat, northern yellow bat, eastern red bat, and Seminole bat. Habitats used during foraging bouts by bats in the state are extremely variable and cover most habitat types available except offshore marine waters.

There are nine colonial roosting and five foliage roosting bat species in South Carolina. Of the colonial roosting species, the big brown bat, tricolored bat, and all of the *Myotis* species are known to hibernate in mines, caves, or tunnels in the state. However, half of all South Carolina bat species may use some level of torpor and wake to forage during warm winter nights. These include colonial roosting species such as the big brown bat, Brazilian free-tailed bat, and northern long-eared bat, and foliage roosting species such as the eastern red bat, northern yellow bat, Seminole bat, and silver-haired bat. Other species are known to be active year round and only enter torpor when the weather is extremely cold, such as Rafinesque's big-eared bat.

Young are generally born between May and June and most bat species in the state produce an average of two young per year, though all except one *Myotis* species gives birth to one per year.

The life span of bats in South Carolina varies by species from an average of two years in the evening bat to a maximum of 30 years in the little brown bat.

Conservation Actions and Strategies

The conservation objectives for South Carolina's bats are to:

1. Develop Specific Action Plans
2. Continue Baseline Population Inventory and Monitoring
3. Maintain and/or Contribute to a Bat Database
4. Protect and Provide Specific Roost Sites
5. Monitor and Mitigate Emerging Threats
6. Identify, Protect, and Enhance Bat Habitat and Drinking Resources
7. Conduct Necessary Research
8. Provide Education, Extension, and Outreach
9. Partner with Agencies, Landowners, and Other Groups
10. Integrate and Maintain the South Carolina Bat Conservation Plan

Monitoring and mitigation efforts for WNS are needed in the state to help prevent or slow the spread of the disease. Efforts that seek to protect and manage bat roosting and foraging habitat are another primary concern. Habitats of high priority have been delineated in the SWAP, and the greatest number of threatened and endangered species fall under four habitat types in the Blue Ridge ecoregion (Appalachian oak forest, high elevation forest, low elevation acidic mesic forest, and low elevation basic mesic forest) and one in the Coastal Plain (mesic forest). Other habitats utilized by over half of the state's highest priority bat species include bottomlands and riparian zones, depressions, hardwood slopes and stream bottoms, maritime forest, pine woodland, river bottoms, upland mixed forest, blackwater stream systems, rock outcrops and sandhill pine woodland.

For South Carolina's bat conservation plan to be successful, complete and reliable information on abundance, distribution, demography, life history, and habitat needs for most of South Carolina's bat species still needs to be determined. Without this basic ecological data, habitat protection plans and land management strategies cannot be fully informed, and therefore may contribute no or very limited benefits toward bat conservation. In addition, partnerships and cooperation between government agencies, private landowners, non-governmental organizations, and the general public are essential if the state is to accomplish its conservation objectives for South Carolina's bat species.

Introduction

Bats are one of the most diverse mammalian orders and compose approximately 25% of all mammals (Neuweiler 2000). With over 1,110 species in the world and 47 resident to the US, bats represent a wide range of morphological and behavioral traits. Worldwide, bats are known to consume fruit, nectar, fish, frogs, birds, mice, and the blood of livestock and wildlife. Though vampire bats tend to give other bats a bad reputation, only three vampire bat species exist in the world and none live in the US. Ecological services provided by bats in the tropics through seed dispersal and pollination are known to be vital to the survival of rainforests (Cox et al. 1991, Hodgkison et al. 2003, Kelm et al. 2008), and a popular alcoholic drink, Tequila, comes from the *Agave tequilana* plant that depends completely on bats for pollination. If that's not persuasive enough information to make one appreciate bats, consider that 70% of all bat species in the world feed exclusively on insects (Neuweiler 2000), and the amount consumed provides a substantial pest control service that would otherwise require costly pesticides. For example, in an eight county region in south-central Texas, this value was estimated at $741,000 annually for cotton producers (Cleveland et al. 2006). In the southwestern U.S. and northern Mexico, the Mexican free-tailed bat (a subspecies of the Brazilian free-tailed bat) provides a total annual cotton pest-suppression service of $11.67 million (López-Hoffman et al. 2014). The estimated annual value of bats in pest suppression services to the US agricultural industry is an estimated $22.9 billion, and is nearly $115 million in South Carolina alone (Boyles et al. 2011). The beneficial ecological effects of bats extend past insect consumption as they also indirectly suppress pest-associated fungus and the toxic compounds they produce in corn, a major worldwide crop (Maine and Boyles 2015). In addition to significant economic advantages, the presence of healthy bat populations and the reduced need for pesticides helps prevent negative effects to many other wildlife species substantially impacted by these chemicals (Pimentel 2009).

Bats have been seen as gods by the Mayans, and are highly regarded in countries like China. For example, the popular Chinese *wufu* symbol of five bats surrounding a stylized tree represents health, wealth, long life, good luck, and tranquility. Through education and outreach, as well as notoriety from WNS that has brought declining bat populations into the public spotlight, bats are beginning to be appreciated by the public and recognized for the major role they play in our ecosystem.

There is great diversity in bat populations across the state due to various roosting habits of South Carolina bats. The state itself consists of a wide variety of habitats, categorized into five distinct ecoregions: The mountainous Blue Ridge near the Appalachians, the Piedmont composed of foothills and midlands, the Sandhills composed of sandy soils and rolling hills along the Fall Line, the Coastal Plain composed of swamps and marshes with rolling hills in the innermost portion and flat plains in the outermost portion, and the Coastal Zone, a warmer, seaward extension of the Coastal Plain composed of sand flats, pine hardwood, swamps, and emergent saltwater marshes (Figure 1). South Carolina commonly harbors 14 bat species, the diversity of which vary geographically across the state (Table 1). Eight bat species occur statewide, and these are also the only bats present in the Piedmont. Incidental records exist of the big free-tailed bat (*Nyctinomops macrotis*) and the federally endangered Indiana bat (*Myotis sodalis*): however, these species are not addressed in this document due to their rarity in the state.

Of the bat species occurring in South Carolina, five are considered foliage roosting bats and nine are considered colonial roosting bats. As the names suggest, colonial roosting bats roost in colonies in winter hibernacula in caves and mines, and foliage roosting bats typically roost solitarily in the foliage of trees. The foliage roosting bats of South Carolina include all of the species in the *Lasiurus* genus and *Lasionycteris* genus and are the eastern red bat, hoary bat, northern yellow bat, Seminole bat, and silver-haired bat. The colonial roosting species include all the species in the *Myotis* genus and the rest of the bats in the state. These are the eastern small-footed bat, little brown bat, northern long-eared bat, southeastern bat, big brown bat, Brazilian free-tailed bat, evening bat, Rafinesque's bat, and tricolored bat.

Like many bat species across the US, the population status and ecology of most bats in South Carolina remain unknown (M. A. Menzel et al. 2003). We seek to summarize available information on legal status, public health, conservation issues, natural history, habitat requirements, species-specific accounts, threats and conservation strategies in 4 chapters: 1. Status and Conservation Issues, 2. Natural History and Habitat Requirements, 3. Species Accounts, and 4. Conservation Actions and Strategies. Chapter 1 is an overview of the legal and conservation status of bats in the state, relationships to public health, and conservation threats and management activities. Chapter 2 summarizes the natural history and habitat requirement of South Carolina's bats. Chapter 3 provides informational accounts of all 14 species on identification, status, life history traits, and specific conservation threats and measures. Chapter 4 is a strategic outline of conservation tasks that could help protect South Carolina's bat populations.

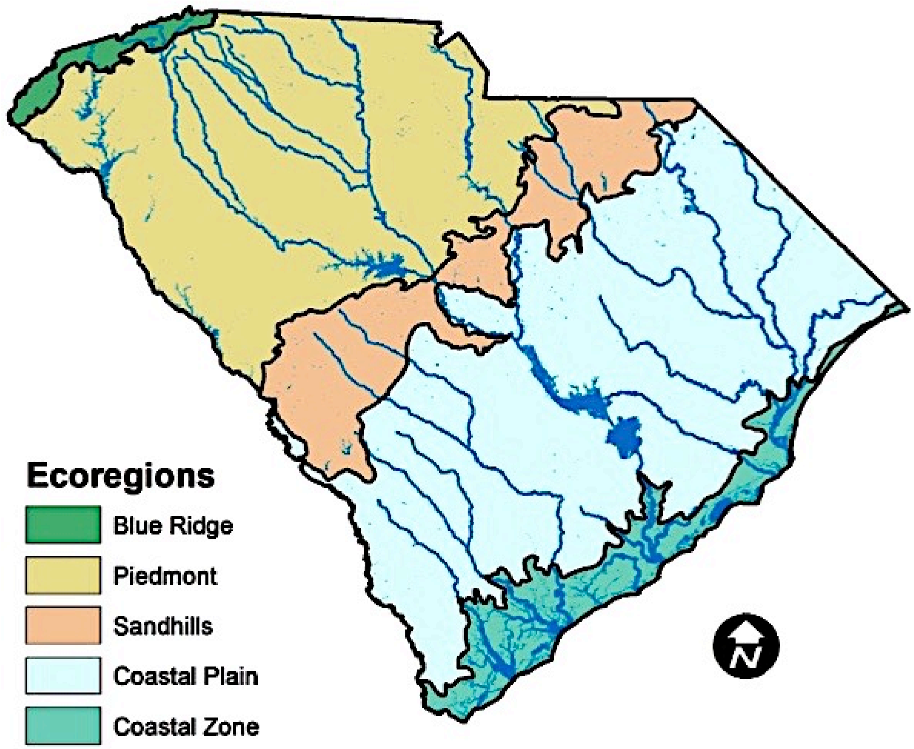


Figure 1: The five ecoregions of South Carolina. Modified from Griffith et al. (2002) for the South Carolina State Wildlife Action Plan (SCDNR 2015). The Coastal Plain-Coastal Zone boundary is modified to conform to the legal delineation of the boundary between freshwater and saltwater zones for fisheries management purposes.

Table 1: Bat species and their associated ecoregions documented in South Carolina. Presence in parentheses (X) indicates that the species is not often found in that ecoregion.

		Ecoregion				
Common Name	**Scientific Name**	**Blue Ridge**	**Piedmont**	**Sandhills**	**Coastal Plain**	**Coastal Zone**
Big Brown Bat	*Eptesicus fuscus*	(X)	X	X	X	X
Brazilian Free-tailed Bat	*Tadarida brasiliensis*	X	X	X	X	X
Eastern Red Bat	*Lasiurus borealis*	X	X	X	X	X
Eastern Small-footed Bat	*Myotis leibii*	X				
Evening Bat	*Nycticeius humeralis*	X	X	X	X	X
Hoary Bat	*Lasiurus cinereus*	X	X	X	X	X
Little Brown Bat	*Myotis lucifugus*	X	(X)	(X)	(X)	(X)
Northern Long-eared Bat	*Myotis septentrionalis*	X			(X)	(X)
Northern Yellow Bat	*Lasiurus intermedius*			X	X	X
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*	X		X	X	X
Seminole Bat	*Lasiurus seminolus*	(X)	X	X	X	X
Silver-haired Bat	*Lasionycteris*	X	X	X	X	X
Southeastern Bat	*Myotis austroriparius*			X	X	X
Tricolored Bat	*Perimyotis subflavus*	X	X	X	X	X
		12	*8*	*12*	*13*	*13*

Chapter 1: Status and Conservation Issues

Legal and Conservation Status

All South Carolina bat species are protected on public lands, including those managed and/or owned by both State and Federal resource agencies such as state wildlife management areas, heritage preserves, and national forests. Additional protection may be provided on lands owned or operated by non-profit conservation organizations such as The Nature Conservancy, National Audubon Society, and local and national Land Trust Organizations.

Federal

Of the 14 bat species in South Carolina, none are federally listed as endangered, one is federally listed as threatened with an interim 4(d) rule (northern long-eared bat), two are being evaluated by the USFWS to determine if listing under the ESA is warranted (little brown bat and tricolored bat), and three are considered at-risk species by the agency (eastern small-footed bat, Rafinesque's big-eared bat, and tricolored bat) (Table 2).

In June of 2011, a status review of the eastern small-footed bat and the northern long-eared bat was initiated. In October 2013, the USFWS announced a 12-month finding on a petition to list the eastern small-footed bat and the northern long-eared bat as endangered or threatened under the ESA and found that the eastern small-footed bat did not warrant listing (USFWS 2013) but proposed a status of Endangered for the northern long-eared bat due to threats from WNS. In April 2015 it was determined the northern long-eared bat met the ESA definition of Threatened, and 30 days later the listing became effective with an interim 4(d) rule providing flexibility to specific entities who conduct activities in northern long-eared bat habitat (USFWS 2015*a*). In April 2016, the US Fish and Wildlife Service determined that designating critical habitat for northern long-eared bats was not prudent, however this species is still listed as threatened under the ESA (USFWS 2016).

Currently, a USFWS petition for the little brown bat (Kunz and Reichard 2010) is under review for a 12-month finding to be completed by the 2023 fiscal year. A 90-day finding determined that action may be warrented and is being evaluated for the tricolored bat (Center for Biological Diversity and Defenders of Wildlife 2016)

Federally threatened northern long-eared bat and 4(d) rule exemptions

The following information from the USFWS (2015) applies to projects that could result in take (defined by the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct") of northern long-eared bats within the range of the northern long-eared bat and the WNS Buffer Zone (see map at https://www.fws.gov/Midwest/endangered/mammals/nleb/pdf/WNSZone.pdf). South Carolina counties within these areas include Abbeville, Anderson, Beaufort, Berkeley, Charleston, Cherokee, Greenville, Laurens, Oconee, Pickens, Spartanburg, Union, and York. Though the section below attempts to explain the interim 4 (d) rule, federal agencies that carry out, fund, or authorize projects that may affect northern long-eared bats are required to have a formal USFWS consultation. A formal consultation is not required only if a federal action agency determines that no effect to northern long-eared bats is expected. For more information, please contact Morgan K. Wolf at (843) 727-

Table 2: Federal and state conservation status of bat species in South Carolina.

		Federal	State		
Common Name	**Scientific Name**	**USFWS[a]**	**SCDNR[b]**	**SCDNR Heritage Trust[c]**	
Big Brown Bat	*Eptesicus fuscus*		SGCN	G5	S5?
Brazilian Free-tailed Bat	*Tadarida brasiliensis*			G5	S4S5
Eastern Red Bat	*Lasiurus borealis*		SGCN	G3G4	S4S5
Eastern Small-footed Bat	*Myotis leibii*	ARS	ST, SGCN	G4	S1
Evening Bat	*Nycticeius humeralis*			G5	S5
Hoary Bat	*Lasiurus cinereus*		SGCN	G3G4	SNR
Little Brown Bat	*Myotis lucifugus*		SGCN, *	G3	S1S2
Northern Long-eared Bat	*Myotis septentrionalis*	T	SGCN, *	G1G2	S1
Northern Yellow Bat	*Lasiurus intermedius*		SGCN	G5	SNR
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*	ARS	SE, SGCN	G3G4	S2
Seminole Bat	*Lasiurus seminolus*		SGCN	G5	S4?
Silver-haired Bat	*Lasionycteris noctivagans*		SGCN	G3G4	SNR
Southeastern Bat	*Myotis austroriparius*		SGCN, *	G4	S1S2
Tricolored Bat	*Perimyotis subflavus*	ARS*	SGCN, *	G2G3	S1S2

[a]U.S. Fish and Wildlife Service: E = Federally Endangered, T = Federally Threatened, ARS = At-Risk Species that the FWS has been petitioned to list and for which a positive 90-day finding has been issued (listing may be warranted); information is provided only for conservation actions as no Federal protections currently exist, ARS* = At-Risk Species that are either former Candidate Species or are emerging conservation priority species.

[b]South Carolina Department of Natural Resources: SE = State Endangered, ST = State Threatened, SGCN = Species of Greatest Conservation Need, * = State Endangered or State Threatened has been proposed.

[c]NatureServe: G = global, S = state, 1 = critically imperiled, 2 = imperiled, 3 = vulnerable to extirpation or extinction, 4 =apparently secure, 5 = demonstrably widespread, abundant, and secure. Rankings taken from Master et al. 2012.

4707 ext. 219, or morgan_wolf@fws.gov at the USFWS Charleston office. Section 9 of the Endangered Species Act prohibits take of a wildlife species listed under the ESA as threatened unless specifically authorized by regulation. Any purposeful take of northern long-eared bats for removal from a human structure, or by individuals authorized to conduct capture or related activities for other bats listed under the Endangered Species Act within one year of the effective date of the interim 4(d) rule, are exempted by the 4(d) rule. To clarify, this means that no permit or consultation is required to exclude northern long-eared bats from a home. Researchers and biologists conducting actions relating to capture, handling, attachment of radio transmitters, and tracking of northern long-eared bats will be required to obtain a federal scientific collection/recovery permit under Section 10(a)(1)(A) of the ESA.

Incidental take of northern long-eared bats is allowed for actions outside of the WNS

Buffer Zone (see map above). Incidental take within the WNS buffer zone not related to specific forest management, native prairie management, minimal and hazardous tree removal, and maintenance or expansion of existing rights-of-way and transmission corridors, as outlined in the 4(d) rule, are not exempted by the 4(d) rule and may require an incidental take permit under Section 10(a)(1)(B) of the ESA. Forest management that converts mature hardwood, or mixed, forest into intensively managed monoculture pine plantation stands, or non-forested landscape, is not exempted under the 4(d) interim rule since these plantations provide poor-quality bat habitat. Minimal tree removal only refers to an impact of one acre or less of contiguous habitat or one acre total within a larger tract. If a northern long-eared bat maternity roost tree or hibernacula has been documented on or near the project area for forest management, native prairie management, minimal and hazardous tree removal, and maintenance or expansion of existing rights-of-way and transmission corridors projects, incidental take will be exempted by the 4(d) rule if activities are not conducted within ¼ mile of known, occupied hibernacula; a known, occupied roost tree from June 1 to July 31 (during the pup season) is not cut or destroyed; and clearcuts are not conducted within a ¼ mile of known, occupied roost trees from June 1 to July 31. Otherwise, an incidental take permit under Section 10(a)(1)(B) of the ESA may be necessary for these activities.

Caves on federal land

Significant caves on federal lands are secured, protected, and preserved by federal land managers through the Federal Cave Resources Protection Act of 1988 (18 U.S.C. § 4301–4309). Caves on federal land generally fulfill the "significant" cave definition, meaning those with characteristics pertaining to biological, geological, mineralogical, paleontological, hydrological, cultural, recreational, educational, or scientific resources. Specific locations of caves and mines are not disclosed for their protection (16 U.S.C § 4304(a)). Additionally, in 2014 the US Forest Service (USFS) authorized continued closure to human entry of all caves and abandoned underground mines in the Southern Region for five years in order to protect caves, mines, and/or associated wildlife species from the spread of *Pseudogymnoascus destructans*, the fungal agent causing WNS, through human transmission (USFS 2014).

State

One bat species in South Carolina is state endangered (Rafinesque's big-eared bat), and one is a "species in need of management" or equivalent to state threatened (eastern small-footed bat). A total of twelve, or 86% of South Carolina's bat species, are on the list of South Carolina's "Species of Greatest Conservation Need" and considered "Highest Priority" in the South Carolina State Wildlife Action Plan (SCDNR 2015) (Table 2). This high proportion is not limited to South Carolina as 15 years ago, before WNS was even detected, 87% of bat species in the Southeast had special conservation designations (Laerm et al. 2000).

State endangered and state threatened bat species are protected under the South Carolina Nongame and Endangered Species Conservation Act (§50-15-10 et seq.). For State endangered species (CL 50-15-30(C), Appendix A), violation of the law is a misdemeanor and a fine of $1,000 or imprisonment up to a year, or both (CL 50-15-80(B), Appendix A). There is less stringent protection for species recognized as state threatened or species "in need of management" (CL 50-15-20(C), Appendix A). This designation roughly parallels the federal threatened species statute and establishes South Carolina Department of Natural Resources (SCDNR) as the authority to engage in conservation activities and develop management programs so these species can "sustain themselves successfully." Violation of this law is a misdemeanor, a fine of up to $500 or imprisonment up to 30 days, and restitution paid (CL 50-15-80(A), Appendix A).

The collection of any bat species in South Carolina for scientific or propagating purposes requires a scientific permit (CR 123-150.3, Appendix A). Violation of the law is a misdemeanor and a fine of between $25 and $100, imprisonment up to 30 days, and revocation of the permit (CL 50-11-1180, Appendix A).

Any bat species may be removed from a home in South Carolina without a permit or consultation. If it is necessary to protect human health and there is no immediate threat to human life, a permit may be issued to remove, capture, or destroy an endangered species. In the case of an immediate threat to human life, no permit is required to remove, capture, or destroy threatened or endangered or species in need of management (CL 50-15-40(E), Appendix A). Additionally, the department may permit taking, possession, transportation, exportation, or shipment of species which appear on the state list of endangered species, or federal list of threatened or endangered species, for scientific, zoological, or educational purposes, for propagation in captivity of such wildlife, or for other special purposes (CL 50-15-40(D), Appendix A).

All South Carolina bats are protected on Heritage Preserves and SCDNR owned lands (CL 50-11-2200 (C), Appendix A). Violation of the law is a misdemeanor, and may require restitution to the land owner, a fine of between $200 and $500 or imprisoned for up to 30 days or both, loss of privilege to enter these lands for two years, and loss of privilege to hunt and fish for one year (CL 50-11-2210, CL 50-11-2220, Appendix A).

The Heritage Trust Program of the SCDNR protects critical natural habitats and significant cultural sites in the form of heritage preserves. This program identifies conservation ranks for South Carolina bat species according to NatureServe criteria, which can be seen in Table 2.

Public Health

Rabies

Rabies is a viral disease transmitted through mammals that infects the central nervous system and is fatal to humans if not treated early. The vast majority of cases reported annually occur in raccoons, skunks, foxes, and insectivorous bats (Center for Disease Control 2015). Transmission usually occurs when infected saliva of a host is passed through bites and scratches, though there have been very rare cases of infected saliva coming into contact with mucous membranes (i.e., eyes, nose, mouth) (Brass 1994). If a suspected or confirmed rabies exposure occurs, development of rabies can be prevented by immediately contacting a doctor and the local health department, and the individual will be treated with a series of intramuscular injections of postexposure prophylaxis of human antirabies immunoglobulin over a 14-day period. For people who handle bats or come into regular contact with wild and feral mammals, such as veterinarians, animal control officers, wildlife biologists and rehabilitators, a preexposure prophylaxis is recommended (Krebs et al. 1995).

In the U.S. annually, the average number of people that die from rabies is one to two, and the animal that caused the infection is not known in the majority of cases. Deaths from rabies in the U.S. often happen because individuals aren't aware of their exposure and don't seek prompt post-exposure treatment. Particularly in developing countries, humans are typically exposed to rabies through unvaccinated dogs and cats. In the U.S., vaccination of dogs has led to a major decline of rabies cases in humans since the 1940s (Brass 1994), and today rabies is limited mostly to contact with wild animals. Exposure to infected bats accounts for many of these wild animal cases since the 1980s (Hoff et al. 1993, Childs et al. 1994, Krebs et al. 1995), and in recent years the proportion of rabies cases from bat bites has increased (Rupprecht et al. 2001). Rabies strains in bats differ from those in terrestrial mammals, meaning it's possible to determine routes of human exposure by animal type. Most human deaths from rabies have been found to be from unrecognized exposure to animals infected with bat-variant rabies (Messenger et al. 2003). In the U.S. from 1980 to 1994, 11 of the 14 confirmed cases of human rabies were linked to bats, eight of which were associated with the rabies virus variant in silver-haired bats (Krebs et al. 1995). Big brown bats, little brown bats, and tricolored bats are species found in South Carolina that could potentially carry this silver-haired bat rabies viral strain (Messenger et al. 1997). Rabies has also been documented in most other bat species occurring in the state, including hoary bat, eastern red bat, northern yellow bat, Seminole bat, eastern small-footed bat, southeastern bat, evening bat, silver-haired bat, Brazilian free-tailed bat, and Rafinesque's big-eared bat (Constantine 1979*a*, J. M. Menzel et al. 2003, Sasse and Saugey 2008). The Centers for Disease Control and Prevention statistics have indicated that only about 10% of all annually reported and confirmed rabid animals are from bats (Krebs et al. 1995). This statistic holds true for South Carolina, as of the 613 animals that tested positive for rabies in the state from 2010 to 2014, 51% were raccoons, 17% skunks, 15% foxes, 8% bats, 5% cats, 2% dogs, and 1% other wild animals (SCDHEC 2014). In a study looking at the distribution of bats species submitted for rabies testing between 1970 and 1990 in South Carolina, 231 out of 2,657 bats submitted were found to be rabid. The eastern red bat was submitted most frequently for testing (30%), and had the highest prevalence of rabies (18%) (Parker et al. 1999). However, bats turned in to be tested compared to those randomly sampled from the environment show very different rates of rabies prevalence, and depends on bat species, colony, and location (Brass 1994, Klug et al. 2011). Klug et al. (2011) studied bat species with the highest reported prevalence of rabies in North America, the hoary bat and the silver-haired bat, and compared bats turned in by the general public to random samples. They discovered that overall rabies prevalence is actually less than or equal to 1%. Though fears and misconceptions about health risks from rabies have resulted in unnecessary eradication (Pierson 1998), the overall human health risks posed by rabid bats in North America is very low and unprovoked attacks by rabid bats on humans is incredibly rare (Constantine 1979*b*, Tuttle and Kern 1981, Krebs et al. 1995, Rotz et al. 1998).

Most routes of contact and potential rabies transmission can be avoided by simple preventive measures. The majority of contact between humans and sick bats occurs when cats bring bats home to their owners (Constantine 2009), and species such as big brown bats that occur in or near buildings may pose a greater risk of rabies transmission to humans (Childs et al. 1994). Preventative measures that reduce the risk of rabies exposure include ensuring dogs and cats are vaccinated against rabies, avoiding handing wildlife, avoiding entry into caves, attics, or abandoned buildings that contain bats, preventing bats from roosting in buildings, and evicting bats through exclusion methods instead of chemical poisons. For a useful guide to bat exclusion, see Bats in Buildings: A Guide to Safe & Humane Exclusions by Bat Conservation International (https://www.batcon.org/pdfs/education/fof_ug.pdf).

Histoplasmosis

Histoplasmosis is a potentially fatal disease affecting the lungs caused by *Histoplasma capsulatum*, a fungus known to thrive in moderate temperatures and moist environments. Spores of this fungus are found in soil with bat or bird droppings, and when the soil is disturbed the spores may be readily released into the air, causing infection through inhalation of the contaminated soil. Symptoms are similar to those associated with the flu and include fever, chills, headache, muscle aches, dry cough, and chest discomfort. The disease can be fatal to infants and individuals with compromised immune systems such as older adults, or to those who may receive high doses such as farmers, cave explorers, or guano miners (De Monbreun 1934, Emmons 1949, American Lung Association 2015).

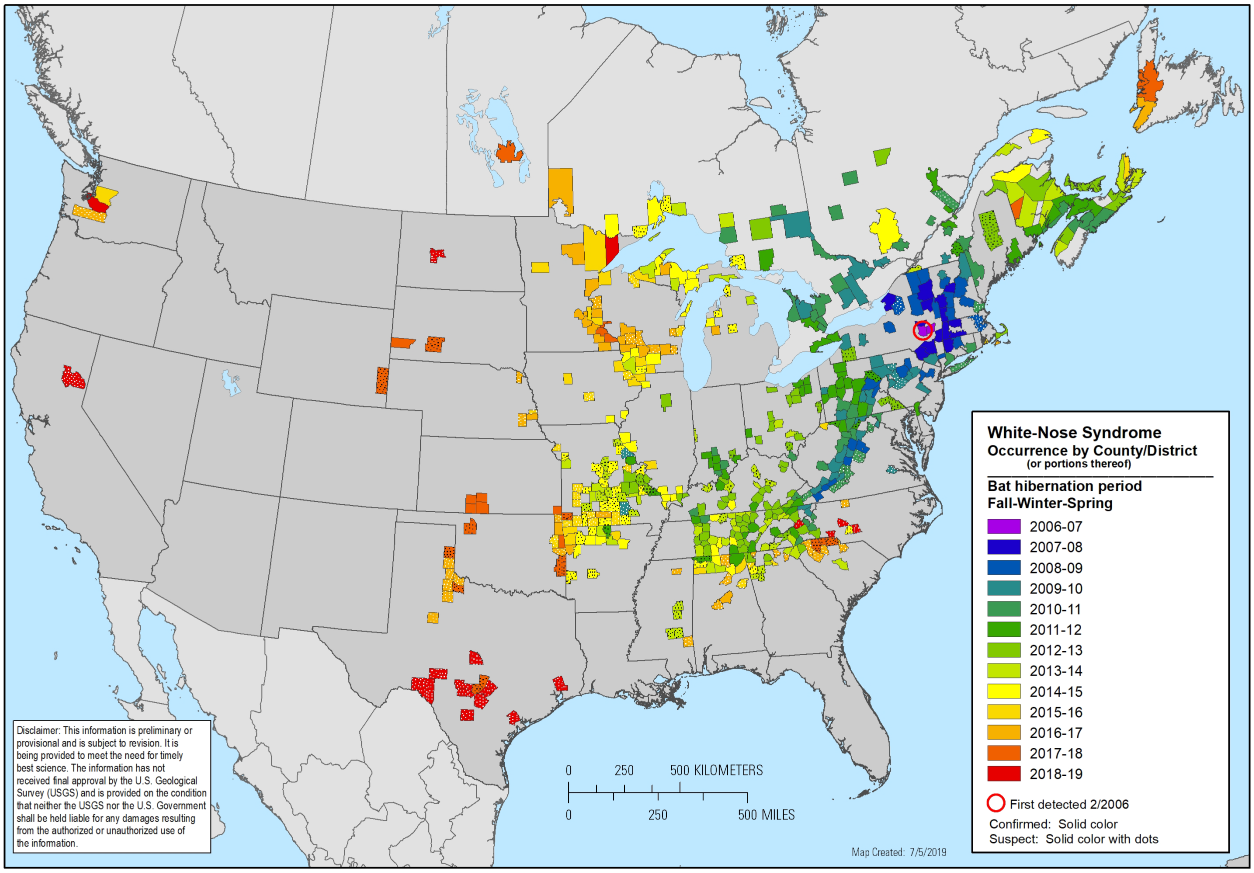
Histoplasmosis is endemic to South Carolina, and in 1979 an outbreak of 10 cases of histoplasmosis occurred following the clearing of a blackbird roosting area (DiSalvo and Johnson 1979). However, the disease is most commonly found in areas surrounding the Ohio and Mississippi River valleys and rates are highest in the Midwest, especially among older adults (Baddley et al. 2011). Preventative measures include avoiding exposure, spraying contaminated soil, and/or using a well-fitting respirator capable of filtering particles with a diameter of two microns (Constantine 1993). Persons working in bat guano should consult the Center for Disease Control website at http://www.cdc.gov/fungal/diseases/histoplasmosis/.

Conservation Issues

White-nose Syndrome

White-nose Syndrome (WNS) is a disease caused by a white fungus species *Pseudogymnoascus* (formally *Geomyces*) *destructans (Pd)* that forms on the nose, wing membranes, and ears of affected hibernating bats. A bat may be infected with WNS and not show signs of fungal growth, so histopathology may be required to confirm the disease (Meteyer et al. 2009). This fungus erodes the outer epidermis and infects underlying skin and connective tissue, causing inflammation. Hypotheses from the ultimate cause of mortality from WNS include the inability to function normally due to skin and wing damage (Cryan et al. 2010), shorter torpor bouts leading to the premature burning of fat reserves and causing starvation (Reeder et al. 2012), or increased evaporative water loss and dehydration (Willis et al. 2011) which could also lead to starvation from frequent waking due to thirst. However, a recent paper by Verant et al. (2014) suggests that fat reserves are prematurely burned before wing lesions or aberrant behavior such as shorter torpor bouts occur.

The devastating effect of WNS on North American bat populations have been unprecedented. Mortality rates attributed to WNS have reached up to 90 and 100% at hibernacula (Kunz and Tuttle 2009) causing the death of between 5.7 to 6.7 million bats in North America since it was first documented in New York during the winter of 2006/2007 (USFWS 2012). By the spring of 2019, WNS had been confirmed in bats in 33 states and seven Canadian provinces, and *Pd* confirmed



Citation: White-nose syndrome occurrence map - by year (2019). Data Last Updated: 7/5/2019. Available at: https://www.whitenosesyndrome.org/static-page/wns-spread-maps.

Figure 2: WNS occurrence in North America, https://www.whitenosesyndrome.org/where-is-wns

in four additional states (Figure 2) (USFWS 2017*a*). In March 2016, WNS was found in Washington state about 1,300 miles from the previous westernmost detection. Recent studies report that *Pd* found in Washington state is genetically similar to strains in the eastern US, suggesting it did not spread from Eurasia but instead from eastern North America (Lorch et al. 2016). Though it is unclear how *P. d.* reached Washington, this is an example of how dramatically WNS can spread.

A ten-fold decrease in the numbers of bats in North American hibernacula has been attributed to WNS, and significant local extinctions in many species have resulted, including up to 69% of former hibernacula of the now federally threatened northern long-eared bat (Frick et al. 2015).

Among bat species currently confirmed to be affected by WNS in other states, six occur in South Carolina. These species are all colonial cavity roosting bats, mainly from the *Myotis* genus. They include the big brown bat, eastern small-footed bat, little brown bat, northern long-eared bat, southeastern bat, and tricolored bat. The southeastern bat was the most recent to be found suffering from WNS, in Alabama in June 2017 (USFWS 2017*b*). Two of the species currently confirmed to be affected by WNS elsewhere have been confirmed with the disease in South Carolina thus far. WNS was first confirmed in South Carolina in Pickens County on a tricolored bat (*Perimyotis subflavus*) in March of 2013.

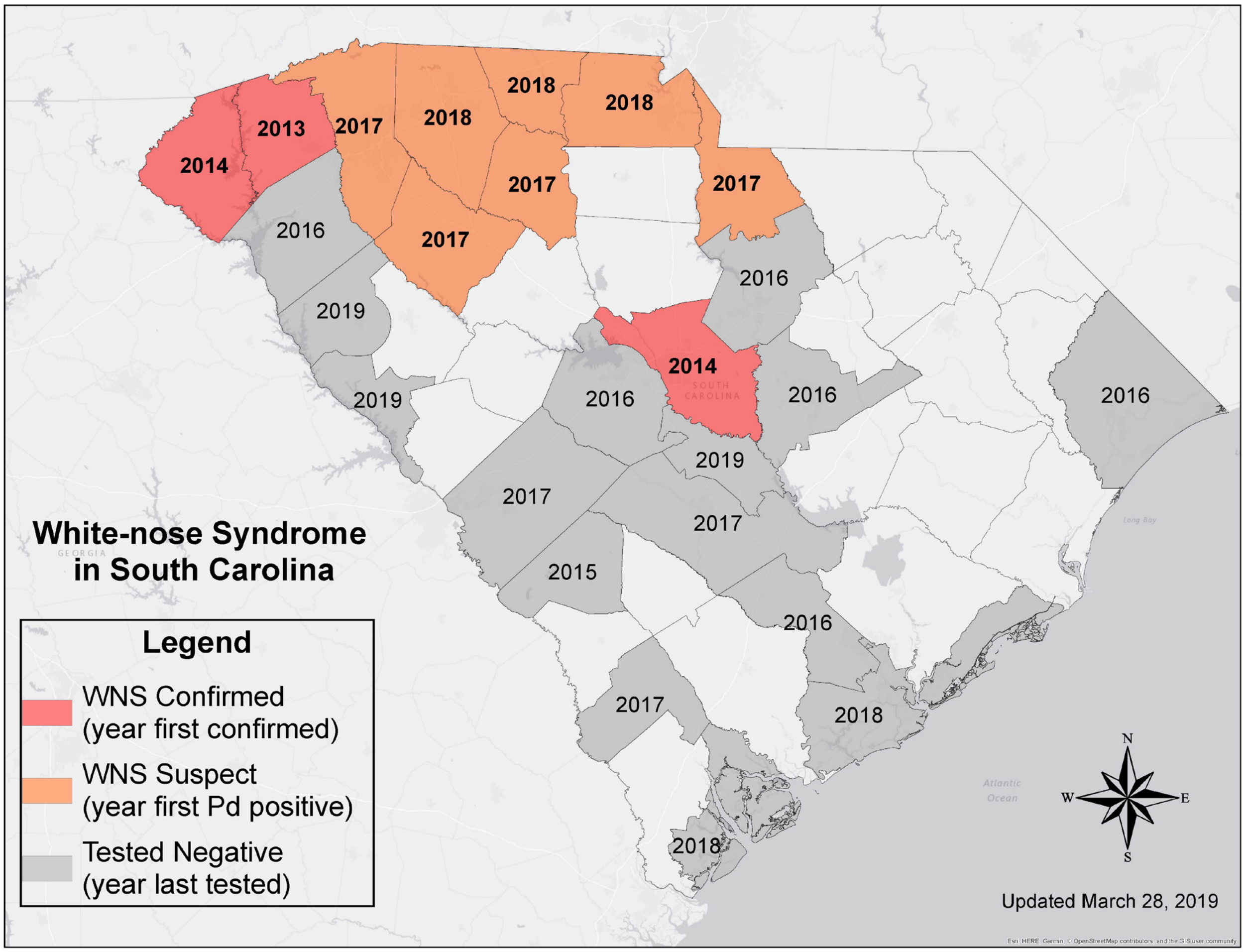


Figure 3: WNS occurence in South Carolina. While dark gray counties had *Pd* negative results, not all potential sites within those counties have been tested. Also, the lack of a positive *Pd* result does not definitively indicate the absence of the organism.

Since then, another case in Pickens county on an eastern small-footed bat (*Myotis lebii*) and two other cases in Oconee and Richland counties on tricolored bats have been reported in 2013 and 2014. Also during 2015, dead tricolored bats were found at the main Stumphouse Tunnel, one of which was tested and confirmed to have WNS. Overall, ten counties in South Carolina are either confirmed (Oconee, Pickens, Richland counties) or suspect for WNS (Cherokee, Greenville, Lancaster, Laurens, Spartanburg, Union, and York). WNS confirmed counties are those where the fungus is present and live or dead bats there have shown signs of being infected by the disease, such as wing damage and fungus growth on the muzzle and/or wings. WNS suspect counties are those where the fungus is present, but no clinical signs of the disease were observed on the bats. In 2017, Greenville, Lancaster, Laurens and Union counties and in 2018, Cherokee, Spartanburg, and York counties were added to the WNS spread map (Figure 3). Three counties (2 in the Piedmont, 1 in the Costal Plain) were tested in 2019, but results came back negative for *Pd*.

Pd has been detected on additional bat species in other states, but have not yet shown diagnostic signs of the disease. These species known to be present in South Carolina include two colonial cavity bat species, the Rafinesque's big-eared bat and Brazilian free-tailed bat, and two species that generally roost in foliage, the eastern red bat and silver-haired bat. The fungus was found on these bats while roosting in caves.

Significant over-winter mortality caused by WNS has been seen in little brown bat, northern long-eared bat and tricolored bat populations (Turner et al. 2011). WNS killed at least one million little brown bats from 2006 to 2010 and caused severe declines in abundance in the eastern portion of its range (Frick et al. 2010*a*, Kunz and Reichard 2010). The core region where much of the global population of little brown bats occur is now infected with WNS, and threatens to push these populations to extinction by 2026 (Frick et al. 2010*a*, Kunz and Reichard 2010). Across large portions of the eastern small-footed bats' range in New York, Massachusetts, and Vermont, populations declined 78% overall between 2006 and 2009 due to this disease (Langwig et al. 2009).Eastern small-footed bats are also at a greater risk of infection by WNS due to their tendency to roost near the entrance of hibernacula where exposure may be increased. Northern long-eared bats are particularly vulnerable to WNS threats due to life history traits that make them slow to recover, such as low fecundity (Caceres and Pybus 1997, Caceres and Barclay 2000). According to Alves et al. (2014), an expected relative population reduction for eastern small-footed bats and northern long-eared bats is estimated to be 71.2% and 31.3% in intermediate population-reduction scenarios, 96.6% and 42.4% in pessimistic scenarios, and 29.3% and 12.9% in optimistic scenarios, respectively. Interestingly, the big brown bat seems highly resistant to WNS, limiting the degree of infection by *P. d.* to the outer epidermis during torpor (Frank et al. 2014).

The common thread between species affected by WNS is that they're colonial cavity roosting bats that hibernate in cold, humid environments. This predisposes them to infection by *P. d.* because the fungus survives in darkness in very similar temperatures from 36 to 57°F (2 to 14°C), (though it thrives in 55 to 60°F, or 12.5 to 15.8°C) and humidity of >90%; and the fact that bats suppress their immune system while in torpor during hibernation (Blehert et al. 2009, Verant et al. 2012, Lorch et al. 2013). According to Hayman et al. (2016), three species that are less severely impacted by WNS select drier areas within their hibernacula (Indiana, eastern small-footed, and big brown bats), while the three species most impacted by WNS select the most humid areas within their hibernacula (little brown, northern long-eared, and tri-colored bats). Also, the rapid spread of the fungus across eastern North America is likely due to the fact that many of these bats hibernate in clusters and healthy bats can readily come in contact with infected bats (Langwig et al. 2012). Additionally, the spores of *P. d.* persist in caves year round and may be spread by humans on gear and clothing (Okoniewski et al. 2010), as well as by other bats and animals.

While there is promising research showing that bacteria native to North American soils (Cornelison et al. 2014) and bacteria from the skin of bats (Hoyt et al. 2015) can inhibit the growth of *P. d.*, there are currently no treatments available to reduce the spread of WNS.

To help reduce the spread of *Pd*, please see the most updated National White-nose Syndrome Decontamination Protocol at https://www.whitenosesyndrome.org/. The most updated South Carolina White-nose Syndrome Response Plan can be found at http://www.dnr.sc.gov/wildlife/bats/batswns.html.

Habitat Loss and Alteration

Urbanization

South Carolina has one of the fastest growing populations in the U.S. (Strom Thurmond Institute 1998). Growing from less than 2.5 million in 1960 to over four million in 2000, it's expected to reach over five million by 2030 (SCFC 2010). Much of this growth results in the conversion of forestland to residential areas in the form of urban sprawl (Macie and Hermansen 2002, Slade 2008).

Urbanization has been cited as the leading threat to southern forests, and Wear and Greis (2011) anticipate a minimum 7% forest loss over the next 50 years. In addition to this is the decrease in the functional value of forests through increased fragmentation, reduced water quality, reduced carbon storage, and increased complexity in the use of fire for forest management practices. According to the South Carolina Forestry Commission (2010), much of urbanized land being converted from highly productive forest land no longer provides water quality protection, and is now uninhabitable to most wildlife species. For example, expanding urbanization is one of the major factors contributing to the loss of bottomland hardwood forest critical to bat species in the southeast (Smith et al. 2009, Loeb et al. 2011). Also, residential development and citrus grove plantations may threaten northern yellow bats if they result in the loss of sandhill and oak hammock habitats (Humphrey 1992). Lastly, the threat of wildfires increases with the increasing human population (SCFC 2010), and blue jays (*Cyanocitta cristata*) in suburban areas may be a potential threat to species such as hoary bats (Bolster 2005).

Though there are programs seeking to mitigate these negative effects and promote healthy urban forests, such as the South Carolina Forestry Commission's Urban & Community Forestry Program, productive forest land habitat needed by bats is often lost through urbanization. In addition, many forms of habitat alteration may inadvertently increase predation by natural predators and unnatural predators such as feral cats.

Agricultural Land Use

Historically, the primary cause of deforestation in South Carolina was due to the conversion of land for agricultural purposes. In the Southeast, 80% of bottomland hardwood forests were converted for agriculture purposes from the time of European settlement until around 1970 (Wear and Greis 2002). However, between 1968 and 2006, South Carolina's agricultural land decreased by 60% or two million acres (SCFC 2010). Today, South Carolina has approximately 4.9 million acres of farmland, or 25.8% of the state's land area (London 2015). The market value (total cash receipts) of agricultural products sold in 2012 totaled over $2.9 billion and the top five agricultural commodities were: 1) poultry (broilers), 2) turkeys, 3) greenhouse/nursery, 4) cotton, and 5) corn (United States Department of Agriculture Economic Research Service 2015).

Conversion of land to agricultural production has been one of the major factors contributing to the loss of bottomland hardwood forest (Smith et al. 2009, Loeb et al. 2011). However, since agricultural lands are now being converted into either urban uses or forest land, loss of habitat from the conversion of forest for agricultural purposes is not a primary concern compared to other threats. Instead however, agrochemicals may negatively impact bat prey availability in existing agricultural areas. A study by Wickramasinghe et al. (2004) found there was a significant increase in insect abundance, species richness, and moth species diversity on organic farms that used no agrochemicals compared to conventional farms, and that five insect families were significantly more abundant on organic farms. No research has been conducted to assess the impacts of agriculture on bats in South Carolina, but in 2011, only 802 acres of the 4.9 million acres of farmland in the state were organic (United States Department of Agriculture Economic Research Service 2015).

Hydrological Alteration

In the past, habitats such as bottomland hardwood forests relied on natural cyclic-flooding events to thrive. Natural riparian areas provided high water quality and benthic habitat in the form of coarse woody debris for insect larvae, prevented sedimentation collection, and provided cooler temperatures from the shade of trees (Gilliam 1994, Broadmeadow and Nisbet 2004, Anbumozhi et al. 2005). Carolina bays also provided various wetland functions such as nutrient cycling and biodiversity conservation (Bennett and Nelson 1991, Sharitz and Gresham 1998).

Disturbance patterns occurring naturally are complicated and influenced by a multitude of variables (King and Antrobus 2001), and the affects of human-made hydrological alterations on these natural processes can have unfavorable and unplanned results on bat habitat through change in forest composition and structure. For example, extensive flooding caused or exacerbated by anthropological land use changes can lead to significant stress on forest productivity (Megonigal et al. 1997) or direct mortality such as in the death of 57,000 bats in Florida (Gore and Hovis 1994). In addition, ditches, channels and impoundments can change water temperature as well as facilitate high sediment loads into wetlands, which affects ecosystem richness and productivity by covering aquatic vegetation, increasing turbidity, and reducing oxygen content. Impoundments also decrease water circulation, preventing outflow of nutrients, changing dissolved oxygen and pH levels, and increasing the accumulation of toxic substances in sediments (US Environmental Protection Agency 1993).

Altered hydrology can also cause habitat fragmentation, which is associated with numerous negative impacts to wildlife (Harris 1988, Fleming et al. 1994). Approximately 97% of Carolina bays have been disturbed in South Carolina (Bennett and Nelson 1991, Sharitz and Gresham 1998), and fragmented bottomland hardwood forests may have a reduced capacity to store flood water, trap nutrients, recharge groundwater, and provide wildlife habitat (Mississippi Museum of Natural Science 2005). Alteration of natural flood regimes may also affect the regeneration of important forest community types such as cypress-gum, thus preventing recruitment of future roost trees (Bunch et al. 2015*b*). Altered hydrological regimes could also cause the outright loss of cypress and tupelo gum swamps, bottomland hardwood, and other forested wetlands, and the loss of these habitats are known to contribute to the decline of bat species (Mirowsky and Horner 1997).

Forest Management

Forestry is the leading manufacturing industry in South Carolina when it comes to employment and labor income, and timber is the number one harvested crop. South Carolina has approximately 13.1 million acres of forest, occupying 68% of the state's land area. Of South Carolina's forests, 53% (6.9 million acres) are characterized as hardwood forest and 47% (6.2 million acres) as softwood (SCFC 2014).

The majority (88%) of South Carolina's forest is privately owned, with individual ownership at 58%, corporate ownership at 24%, and forest industry at 6% (Figure 4). Only 12% is owned by public agencies, and includes national forests at 5%, state, county and municipal lands at 4%, and other federal land at 3% (SCFC 2010, Conner 2011).

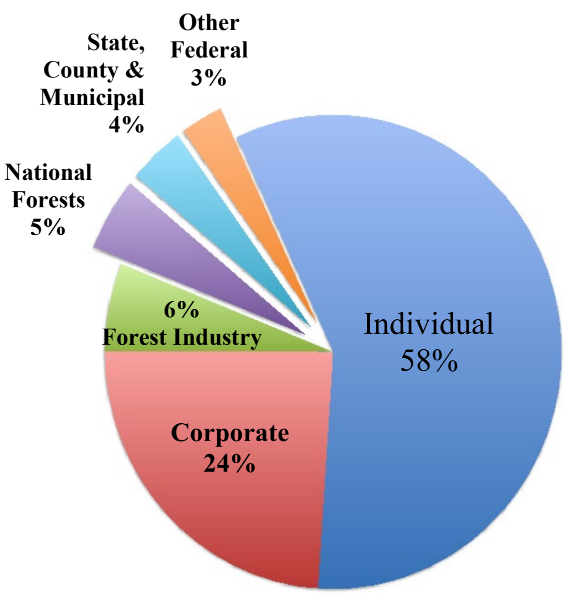


Figure 4: Forest land ownership in South Carolina (SCFC 2010, Conner 2011).

Forest industry has declined markedly in the past decade, and between 2001 and 2012 it was reduced by 88%. This decline continues today as forest land is transferred to private individuals and non-forest industry corporations. Because 11 million of the 13 million acres of forest are privately owned, this land is at risk for development. About one-fifth of these private individuals considered timber products from their land an important management objective, but there is concern that these forests will become increasingly parceled into smaller holdings, fragmented, and/or converted to non-forest uses (SCFC 2010).

Forests in the South have been fragmented and reduced in functionality and extent from various causes including timber harvesting practices (Noss et al. 1995, Wear and Greis 2002). Forest management has direct and indirect impacts on bats since these species have a close association with forest structure and vegetation (Guldin and Emmingham 2007). The felling of trees and snags, building of roads, disruption of boulders in quarries, prescribed burns, and vegetation and insect control are all forestry practices that can result in direct mortality of bats (Hayes and Loeb 2007). Indirect impacts from forest management have the potential to be greater and make lasting affects on bat populations due to their cascading nature. For example, the removal of mature, large-diameter trees and snags through commercial timber operations in the southeastern US (Gooding and Langford 2004, Wilson et al. 2007) reduces important roost availability for many bat species since tree size and stand age are important indicators of cavity abundance (Allen and Corn 1990, Fan et al. 2003, Barclay and Kurta 2007). The loss of existing snags and curtailed development of large snags from forestry practices means less maternity and roosting sites for silver-haired bats (Campbell et al. 1996, Mattson et al. 1996, Betts 1998). Additionally, loss and degradation of bottomland hardwood forest habitat through clearing and drainage along with the disappearance of extra large tree hollows has likely been a contributing factor in the vulnerability of Rafinesque's big-eared bats (Tiner 1984, Clark 2000, Mitsch and Gosselink 2001). Even if roosts aren't directly affected, forest fragmentation around roosts may increase the distance bats have to fly in order to find suitable foraging and drinking areas, and can lead to long-term declines in bat colony sizes (Clark 1990, Hurst and Lacki 1999, Adams and Hayes 2008). Forest management activities such as thinning effect the amount of vegetative clutter and tree density in a forest, which are factors strongly related to bat activity and can actually have a positive impact on certain species (Hayes and Loeb 2007). Additionally, because riparian zones are important to bats, providing a riparian zone buffer during timber harvests would help minimize the impact to bats. The functional width of riparian buffer zones near small streams, according to a study by O'Keefe et al. (2013), is greater than or equal to 32 feet (10 m). However, research on larger buffer zone sizes still needs to be conducted.

Currently, South Carolina has more forest land and timber volume than ever recorded. However, due to the creation of large portions of young forest in a short period of time through the Conservation Reserve Program and Hurricane Hugo reforestation efforts, much of these tree stands are of similar age (SCFC 2010). This lack of age and size class diversity does not provide as wide an array of habitat for bats as a similar area with more diversity might. Studies show that monotypic stands don't provide quality foraging areas for bats, as the abundance of moth prey is reduced and foraging success is lowered (Summerville and Crist 2002, Lacki and Dodd 2011). For example, even-age timber management practices could have an adverse affect on the threatened northern long-eared bat because mature forest stands are important habitat to this species (Caceres and Pybus 1997). Destruction and fragmentation of mature forests in the mountains and Coastal Plain of South Carolina is also a major threat to Rafinesque's big-eared bats and southeastern bats because they depend on these areas for foraging and roosting (Bunch et al. 2015*b*).

Additionally, forestry management practices using a shorter rotation with altered composition of tree species can eventually create a less complex, relatively uniform overstory and a denser understory (Guldin and Emmingham 2007). Management that allows for variation in tree densities (Patriquin and Barclay 2003) as well as a diverse array of herbaceous and woody plants could play a positive role in bat species richness by providing important habitat necessary for the development of prey species consumed by bats such as Rafinesque's big-eared bats (Dodd et al. 2008, Lacki and Dodd 2011). Forestry practices may also impact some of the most sensitive natural habitats in the state such as caves, sinkholes, and springs (SCFC 2010). These environments are important areas for bats as they provide hibernacula and, especially during periods of drought, key water resources.

Prescribed fire during cold weather may also pose a threat as eastern red bats (Mager and Nelson 2001) and other lasiurine bats are known to use leaf litter during hibernation (Moorman et al. 1999, Rodrique et al. 2001, Hein et al. 2005, Mormann and Robbins 2007). If prescribed burns are conducted during colder winter periods (e.g < 60°F (15°C)), bats roosting beneath leaf litter may be in deep torpor and less likely to escape approaching flames then during warmer periods when they are in shallow torpor (Perry and McDaniel 2015). Increased wind speed during prescribed fires has been found to decrease latencies of response behavior in torpid red bats, as smoke propelled by wind greatly increases bat awareness (Layne 2009).

Loss of Anthropogenic Roosting Habitat

Anthropogenic structures such as mines, wells, cisterns, buildings, and bridges can provide habitat for many species of South Carolina's bats. However, when these structures are closed, filled in, taken down, or renovated to newer designs, bats may lose important roosting or maternity sites (Clark 1990, Keeley and Tuttle 1999, Sherwin et al. 2009). Mine closures can make a significant impact as destruction of hibernacula is the main factor in population declines of bat species dependent on caves and mines (Humphrey 1978, Sheffield and Chapman 1992). The direct impact of mine closures cause bat mortality if they occur during hibernation. Indirect impacts during non-hibernating periods may force bats such as the federally threatened northern long-eared bat to burn critical fat reserves while searching for new hibernacula (USFWS 2011). Also, human-made structures that more recently took the place of tree hollows as colonial roosts are being lost in some areas of the southeast (Clark 1990, Belwood 1992, Lance 1999).

Loss of Spanish Moss and Palm Fronds

The loss of Spanish moss due to a fungal infection poses a big threat to the roosting habitat of northern yellow bats and Seminole bats. Loss due to fungal infection is a possibility due to an outbreak during the 1960's that caused Spanish moss to be eliminated from many areas of central Florida (Smith and Wood 1975, Jensen 1982). The harvesting of Spanish moss may be a problem for these bat species in some areas. However, the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). Habitat and roost site loss due to the removal of palm fronds is another potential issue for northern yellow bats, evening bats, and Seminole bats (Mirowsky 1997, Bunch et al. 2015*c*).

Sudden Oak Death

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock (Bunch et al. 2015*b*).

Feral Hogs

Feral hogs can negatively alter bat habitat by influencing future overstory composition, reducing tree diversity, decreasing plant cover and surface litter, and changing soil composition and chemistry (Siemann et al. 2009). Hogs could also potentially forage on bats roosting in the leaf litter.

Human Disturbance

Disturbance and vandalism of hibernacula by human activities poses a major threat for hibernating bat species (Tuttle 1979, Thomas et al. 1990, Caceres and Pybus 1997). Along with disturbance during summer maternity periods, these threats are a significant factor in the widespread decline of species dependent on caves and mines (Humphrey 1975, Sheffield and Chapman 1992, Amelon and Burhans 2006*a*). There are numerous reports of roosting and nursery colony abandonment due to excessive disturbance, banding and radiotelemetry studies, and survey and netting operations (Watkins 1969, Bain 1981, Clem 1992). Other examples of human disturbance that have lead to abandonment include vandals, careless cave explorers, blocking caves with rocks, setting guano piles on fire, and turning caves into dump sites (Rice 1957, Mount 1986, Gore and Hovis 1994). Mass die-offs of little brown bats at hibernacula not related to WNS have been associated with vandalism (Gould 1970).

Disturbance to hibernacula causes bats to deplete their fat supplies and abandon caves, such as with the threatened northern long-eared bat (Caceres and Pybus 1997). The loss of energy stores may affect overwinter viability as well as other life history events, such as the lowering of reproductive rates due to bats being significantly smaller during the reproductive period (Reichard and Kunz

2009). Disturbance to maternity colonies may lead adults to inadvertently knock young from the roost in their haste to leave, causing juvenile mortality (Foster et al. 1978, Hermanson and Wilkins 1986).

Climate Change

Global climate change is a potential threat to bat species due to the predicted rise in regional temperatures (IPCC 2012). Bats depend highly on temperature for important life history processes such as hibernation, reproduction, and growth, so a change in climate could potentially cause earlier hibernation emergence, extended foraging seasons, and earlier birth of young (Jones et al. 2009).

Bat habitat is also threatened through drought and heat stress associated with climate change (Hanson and Weltzin 2000, Rennenberg et al. 2006, Allen et al. 2010), which has the potential to cause increased tree mortality, insect outbreaks and wildfire. Additionally, roost sites may change as the shift in temperature and precipitation patterns predicted by various climate models alters vegetation (Prentice et al. 1991, Ayres 1993). These changes may make habitat unsuitable and ultimately modify bat distribution through the shifting of their range, as it has with wildlife in other areas (Pörtner and Farrell 2008, Loarie et al. 2009, Loeb and Winters 2013). Migratory bats may also be negatively affected by habitat degradation from climate change (Robinson et al. 2009). Continued change in temperature and precipitation may also alter the availability of insectivorous prey (Bale et al. 2002, Robinson et al. 2009). Climate change has been documented as negatively affecting songbird populations in this way (Strode 2003, Both and Visser 2005).

Though some climate models predict an increase in violent weather events that could affect bat populations in fragmented habitats, the Intergovernmental Panel on Climate Change (IPCC) report on extreme weather events states a lack of strong evidence to support this (IPCC 2012).

Specifically for hibernating bats in South Carolina, the temperature at southern hibernation sites may become too warm and/or fluctuate too greatly. This threat has the potential to cause bats such as the eastern small-footed bat to deplete energy reserves through more frequent arousal from torpor since it hibernates in areas more susceptible to fluctuations in temperature (Humphries et al. 2002, Rodenhouse et al. 2009). However, the exact role that climate change will play in the state on bats and their habitat is largely unknown due to climate model limitations and inadequate experimental data. But if prolonged drought conditions occur, the recruitment of tree species specific to wetlands and bottomland hardwoods would be impacted, and those lands may also become more susceptible to conversion and development (BCI and SBDN 2013).

Wind Energy Development

Wind turbine facilities are a threat to many bats as an estimated 450,000 bat fatalities occur at these locations annually in North America (Ellison 2012). This threat can come from direct mortality caused by either blade strikes or through barotrauma where a sudden change in air pressure near the blades causes damage to lung tissues of bats (Kunz et al. 2007, Baerwald et al. 2008). In addition, habitat loss and fragmentation is associated with construction of these facilities (Arnett et al. 2007). Wind turbine facilities in North America have been increasing in recent years and are expected to continue as the demand for energy increases and fossil fuels become less popular due to sustainability issues, environmental impacts, and wildlife concerns

(Inkley et al. 2004, Kuvlesky et al. 2007, Arnett et al. 2008). Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007, Arnett et al. 2008), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). In fact, many of the highest mortalities reported come from wind energy sites on forested ridges in the eastern US at 15 to 41 bats killed per megawatt per year (Kunz et al. 2007). Also, estimates of mortality from wind turbines are likely underestimated due to the challenge in finding all carcasses, and the impact from these fatalities may have a cumulative effect on bat populations due to their low reproductive rates.

The majority of wind turbine related deaths is composed of migratory bat species such as eastern red bats, hoary bats, and silver-haired bats, especially during later summer and early fall (Ellison 2012). Hoary bat fatalities are the most prevalent and compose about half of the 450,000 annual bat fatalities at wind facilities in North America, while silver-haired bat mortalities compose about one-fifth of that estimate (Cryan 2011, Ellison 2012). Eastern red bats are also often one of the top species recorded with the most bat fatalities (Ellison 2012). Fiedler (2004) found that 61.3% of the bat fatalities at a wind farm in eastern Tennessee were eastern red bats. The reason wind energy poses a larger risk to migratory bats is likely due to seasonality and migration patterns that make them more vulnerable to collisions (Cryan 2011), such as the use of ridge tops by bats during migration (Johnson and Erickson 2008).

Though the percentages of direct fatalities are low compared to migratory tree bats, wind energy also threatens other species found in South Carolina including tricolored bats, Brazilian free-tailed bats, northern long-eared bats, small-footed bats, little brown bats, and big brown bats. Wind turbines pose a threat to tricolored bats, especially if erected near roosts, colony sites, and along migratory pathways, as mortalities have been reported at multiple wind-energy facilities in the US (Ellison 2012). This species is frequently killed by wind turbines, and deaths may account for up to 25% of total bat deaths (Arnett et al. 2008). Piorkowski and O'Connell (2010) showed a steady rate of collision mortality of Brazilian free-tailed bats at the Oklahoma Wind Energy Center, and reported that of the seven bat species killed by wind turbines, 85% of all bat fatalities were Brazilian free-tailed bats. Wind energy development also threatens northern long-eared bats through direct mortality and the clearing of mature forests for turbines and road construction (Kerns and Kerlinger 2004, Johnson 2005). Because the eastern small-footed bat tends to roost in talus areas occurring on ridge tops, wind power development may adversely affect this species through habitat loss from construction as well (Amelon and Burhans 2006*b*). Little brown bats and big brown bats comprise a small percentage of total fatalities at wind energy developments in the US compared to other species, with little brown bats comprising 5.9% and big brown bats only 1.9% (Johnson 2005). No reports of southeastern bat mortalities by wind turbines have yet been reported, but since other *Myotis* species have been affected, this species may be vulnerable if wind facilities are built near their colonies. The effects of potential off-shore wind farms on bats such as the northern yellow bat are unknown.

No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Also, areas of the southeast have ideal wind development areas including high-elevation mountain tops, plains, and coastal areas, and Federal Aviation Administration databases indicate numerous proposals for wind energy development across the southeast (BCI and SBDN 2013). It is possible to reduce bat mortality from wind energy by feathering turbine blades (turning them parallel to the wind, affectively idling them) and increasing the cut-in speed. In a synthesis of studies on reducing bat fatalities at wing energy facilities, Arnett et al. (2013) reported that when turbine cut-in speed was increased between 1.5 and 3.0 m/s there was at least a 50% reduction in bat fatalities, and that feathering resulted in up to 72% less bat mortality when turbines produced no electricity for the power grid. In fact, 17 members of the American Wind Energy Association have recently recognized this and volunteered to idle turbines at low wind speeds during peak migration season, potentially reducing bat fatalities at wind farms by 30% (Curry 2015).

Environmental Contaminants

There is increasing evidence that a considerable factor in the decline of bats is exposure to environmental contaminants (Gerell and Lundberg 1993, Clark 2001, Hickey et al. 2001). Pesticide poisoning, especially by organochlorines and anticholinestrase, has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides on forested public lands can cause mortality to both bats and their prey (Bolster 2005). For example, when applied for control purposes they can cause direct mortality to little brown bats, or indirect mortality through their insect prey (Kunz et al. 1977). Pesticides can also alter bat behavior and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Additionally, bats may suffer a delayed affect when high levels are released from stored fat deposits metabolized during weaning, migration, or at the end of hibernation (Geluso et al. 1976, Bennett and Monte 2007). Bat species that consume large amounts of crop pests may have an increased risk of contamination from the accumulation of organochlorine pesticides in body fat. For example, population declines of the Brazilian free-tailed bat reported over the last 50 to 100 years in the US may partially be due to direct or indirect poisoning by pesticides and heavy metals (McCracken 1986, Gannon et al. 2005). Rafinesque's big-eared bat may also be vulnerable to pesticides given the reliance this species has on moths (Hurst and Lacki 1999, Lacki and LaDeur 2001). Potentially, deforestation from gypsy moths (*Lymantria dispar*) and/or control measures for gypsy moths, such as broadcast usage of *Bacillus thurinigiensis* var. *kurstaki* may impact Rafinesque's big-eared bats (Bunch et al. 2015*b*).

Contaminants of emerging concern, such as flame retardants, pharmaceuticals and personal care products, have been discovered in high concentrations in bats. A recent study by Secord et al. (2015) found that out of 48 bat carcasses collected in the northeastern US, 100% showed high detection frequencies of polybrominated diphenyl ethers (PBDEs), or flame retardants, in their system. Also in relatively high detection frequencies were salicylic acid (81%), thiabendazole (50%), caffeine (23%), and in at least 15% were compounds such as ibuprofen, penicillin V, testosterone, and DEET. Though it is not known how these chemicals affect bats, it is possible that they could make them more susceptible to WNS, or in the case of caffeine, arouse bats out of hibernation prematurely.

Elevated levels of contaminants such as heavy metals like mercury have been found in bats, and can be toxic in high concentrations. In a South Carolina study on Rafinesque's big-eared bats, Bennett et al. (2003) found elevated levels of Al, Cd, Cr, Cu, Hg, Ni, Pb, and Zn in all hair samples measured, and As and Se in the majority of samples. The Al (aluminum) concentrations in hair samples were an order of magnitude higher than those found in little brown bats in Ontario and Quebec. Other concerning results were the levels of Pb (lead) and Hg (mercury), which are considered highly toxic to wildlife. Of the samples measured, 24 % had an amount of lead greater than the lower limit considered toxic. Even worse, 55% of the samples had mercury near or above the level at which detrimental effects have been recorded in humans and rodents. Many bats, such as the silver-haired bat, may be particularly vulnerable to heavy metal contamination due to their tendency to forage over water. Eastern small-footed bats may also be particularly vulnerable to environmental contaminants due to their small body size and association with mining activities (Amelon and Burhans 2006*b*). Waterways in South Carolina with mercury and PCB advisories can be seen at http://www.scdhec.gov/FoodSafety/Docs/FISH2015.pdf

Other Threats

Inadequacy of Existing Regulations

The inadequacy of existing regulations for the management of forestry, wind energy development, and oil, gas, and mineral extraction when it comes to the protections afforded a state-listed species is another potential threat to South Carolina's bats. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011).

Collisions from Buildings

Large buildings also pose a collision threat to some migratory species such as eastern red bats (Timm 1989). Additionally, small numbers of deadly collisions with towers in Florida have been recorded for Seminole and southeastern bats (Crawford and Baker 1981). In South Carolina, the carcass of a hoary bat that hit a power line exists at the Campbell Museum of Natural History. However, the level of impact from tower or building mortalities on local or range-wide populations is a relatively minor threat.

Current Conservation, Management, and Outreach Activities

Surveys and Research

Past and Current Surveys and Research

One of the earliest comprehensive reports on the species, distribution and natural history of 11 of the 14 bats in South Carolina was provided in a general mammal survey of the state by Golley (1966). That information was updated by Neuhauser and DiSalvo (1972) with the first record of a southeastern bat in the state, new county records for other bats, and expanded ranges for Seminole and Brazilian free-tailed bats. Using bats submitted for rabies testing, DiSalvo et al. (2002) further updated these bat species distributions. One year later J. M. Menzel et al. (2003) contributed additional information to the South Carolina bat distribution maps from museum records, captures reported in literature, and records maintained by SCDNR.

Most research specifically investigating natural history of South Carolina bats did not begin until the late 1980's. Results from these early bat surveys exist in internal documents but are reflected in the Campbell Museum of Natural History records at Clemson University. Available studies from the late 1990's ranging from topics on diet, roosting habits, foraging habits, and species prelisting recovery come in the form of survey reports (Cothran et al. 1991, Bunch et al. 1997, 1998*a*, *b*, Bunch 1998, Bunch and Dye 1999*a*, *b*, Louie et al. 2001), unpublished master's theses (Carter 1998, Menzel 1998), and an honors project (Donahue 1998).

Between 2000 and 2003, a large portion of bat research was conducted in the Sandhill ecoregion at the U.S. Department of Energy's Savannah River Site on 12 of the 14 bat species of South Carolina (Menzel et al. 2000*a*, 2001*c*, 2002*d*, *b*, M. A. Menzel et al. 2003). These studies focused on foraging ecology, tree roost selection, home range, habitat use, diet, and spatial activity patterns. Since 2003, research studies on specific bat species and communities in various regions of the state have been conducted on bat activity (Menzel et al. 2005*b*, Hein 2008, Loeb and Waldrop 2008, Moore 2015), community and social structure (Loeb et al. 2009, Loeb and Britzke 2010), diet (Armbruster 2003, Carter et al. 2004), presence and absence (Ford et al. 2006*a*), habitat use (Loeb and O'Keefe 2006), roost site selection (Leput 2004, Hein et al. 2005, 2008*a*, Bennett et al. 2008, Loeb and Zarnoch 2011), variation in metal concentrations (Bennett 2004), and the presence or absence of rare, threatened, and endangered species (Webster 2013). Current studies include research lead by Susan Loeb on foraging and roosting habitat of southeastern bats at Congaree National Park and an ongoing study on band injury rates of big brown bats. Results from the master's thesis of Ben Neece, analyzing echolocation calls collected in SC through the North American Bat Monitoring Program, should become available in late 2017.

South Carolina bat surveys are generally conducted by SCDNR and the USFS. SCDNR has conducted multiple surveys at the Army National Guard's McCrady Training Center (previously known as the Leesburg Training Site) in the Sandhills ecoregion of the state (Bunch et al. 1997, 1998*b*) and the Naval Facilities Engineering Command in the Coastal Zone ecoregion (Bunch 1998, Louie et al. 2001). Winter hibernacula counts in the Blueridge and Piedmont ecoregions are the largest ongoing surveys and are conducted on a three to five year rotation by SCDNR. The USFS Southern Research Station has been conducting annual winter counts at the Clemson University owned railroad tunnel for the past three years.

The most information collected on a single species in South Carolina thus far has been on Rafinesque's big-eared bat. This is probably due to its long standing status as state endangered, and the fact that relative abundance and distribution of the species are not easily estimated due to capture and detection challenges.

The North American Bat Monitoring Program (NABat) (Loeb et al. 2015), a nation-wide, long-term acoustic monitoring effort was started and run in South Carolina from 2015-2016 by master's student Ben Neece and Dr. Susan Loeb from Clemson University. SCDNR partnered with the university as well as USFS Southern Research Station, USFWS, and others to help initiate the program in SC. Standardized acoustic sampling of bat calls are surveyed using 38, 10 X 10 km cells generated randomly across the state by the USGS. Stationary site and mobile route surveys are conducted annually from May to July, and the effort for these surveys depend heavily on volunteers and state and federal organizations across the state. SCDNR ran the program in the summer of 2017, and hopes to do so into the future.

Habitat and Species Protection

Lands protected in South Carolina by federal, state, or nonprofit conservation organizations conserve a total of 11% of the state. Overall conservation acreages in the state include 469,000 (190,000 ha) for state-owned, 990,000 (400,000 ha) for federally owned, 671,000 (272,000 ha) for privately owned, and 91,000 (37,000 ha) for military owned lands (SCDNR 2015). The Blue Ridge ecoregion has the greatest percentage of land conserved at 57%, where approximately 163,000 acres (66,000 ha) are protected by preserves, conservation easements, and national forests such as Ashmore Heritage Preserve, the South Saluda watershed of the Greenville Water System, the Andrew Pickens District of Sumter National Forest, and the Mountain Bridge Wilderness Area (Bunch et al. 2015*b*). For the other ecoregions, 29% of the Coastal Zone, 14% of the Sandhills, 10% of the Coastal Plain, and 6% of the Piedmont at 6% are protected (SCDNR 2015). In terms of the largest number of acres protected, the Coastal Plain is responsible for 39% of South Carolina's conserved land, with federal lands and public ownership playing major role in habitat protection. In this ecoregion, Congaree National Park encompasses nearly 27,000 acres (10,926 ha) and is the largest old growth bottomland hardwood forest in the southeastern US. Also, Francis Beidler Forest, owned by the Audubon Society, protects 16,000 (6,475 ha) acres of old-growth swamp.

As mentioned in the Legal and Conservation Status section of this document, bat species are protected on Heritage Preserves and SCDNR owned lands (CL 50-11-2200 (C), Appendix A). The Heritage Trust Program protects critical natural habitats and significant cultural sites in heritage preserves, and identifies conservation ranks for South Carolina bat species according to NatureServe criteria (Table 2). The Heritage Trust Program also maintains a database with current and historical bat data that's been collected in the state. Other SCDNR habitat protection programs include the Forest Legacy Program, Focus Area Program, ACE Basin Project, Scenic Rivers Program, South Carolina Conservation Bank Act, National Estuarine Research Reserve System, South Carolina Land Trust Network, and Beach Sweep/River Sweep (SCDNR 2015).

Conservation Plans and Recommendations

The South Carolina SWAP identifies 12 of the 14 bats in the state as species of conservation concern or greatest conservation need (Table 2) (SCDNR 2015). Conservation recommendations for these species are provided in the Supplemental Volumes of the plan and titled Colonial Cavity Roosting Bats Guild, the Foliage Roosting Bats Guild, and Silver-haired Bat (Bunch et al. 2015*b*, *c*, *a*). These recommendations include specific information for management, priority research and survey needs, monitoring, education, public outreach and cooperative efforts in South Carolina.

"A Conservation Strategy for Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*) and Southeastern Myotis (*Myotis austroriparius*)" (BCI and SBDN 2013) is an extremely detailed plan developed to help guide conservation and management of these South Carolina bat species. Also, the symposium on the "Conservation and Management of Eastern Big-eared Bats" (Loeb et al. 2011) is particularly useful for information regarding the conservation needs and management of Rafinesque's big-eared bats. The "Conservation Assessments for Five Forest

Bat Species in the Eastern United States" consolidated and synthesized by the USFS (Thompson 2006) provides conservation information for the southeastern bat, eastern small-footed bat, northern long-eared bat, tricolored bat, and evening bat. In this document, potential threats, estimates of habitat availability, and percentages of protected habitat available within the National Forest System are outlined. Additionally, estimates of habitat availability are shown in the form of acreage across ownerships, such as federally owned, State-owned, county or municipal-owned, and privately-owned lands.

Educational Outreach

Current Informational and Bat Management Materials

Informational materials on South Carolina bats are largely provided by SCDNR. The department contributed to a major educational outreach tool, the "Bats of the Eastern United States" bat identification poster, which is provided for free to the public. Other materials can be accessed on the SCDNR website, and the following are descriptions and links to these documents.

SC bats in buildings - written specifically for the public, this document provides information on the bats of South Carolina, how to safely exclude them from structures and living quarters, and provides links on how to build bat boxes and report South Carolina bat colonies.
http://www.dnr.sc.gov/wildlife/publications/nuisance/SCbatsinbldgs.pdf

Bats and White Nose Syndrome (WNS) - this webpage describes WNS, why it's a problem, what SCDNR is doing about it, and what the public should do if a dead bat is found. It also provides links to the recently updated South Carolina WNS response plan, a document on the Bats of the Southern Appalachians, an informative USFS video, and additional information on WNS.
http://www.dnr.sc.gov/wildlife/bats/batswns.html

The South Carolina SWAP link provides the entire action plan for the state:
http://dnr.sc.gov/swap/index.html. Bat species information in the SWAP is found under the Supplemental Volume, Mammals section. For the Colonial Cavity Roosting Bats Guild:
http://dnr.sc.gov/swap/supplemental/mammals/colonialcavityroostingbatsguild2015.pdf
For the Foliage Roosting Bats Guild:
http://dnr.sc.gov/swap/supplemental/mammals/foliageroostingbatsguild2015.pdf
For the Silver-haired Bat:
http://dnr.sc.gov/swap/supplemental/mammals/silverhairedbat2015.pdf

The Rare, Threatened and Endangered Species Inventory link lists these species in South Carolina by county:
http://www.dnr.sc.gov/species/index.html

Bat Conservation Organizations

National and Regional Levels

A major player on the national level of bat conservation is Bat Conservation International (BCI), a non-governmental organization that works to conserve the world's bats and their ecosystems. In the US, they have conducted research and conservation activities to protect habitat, mitigate threats to bats, and educate the public. Specifically, they help safeguard critical bat colonies in Texas and Alabama, address the threat of wind energy and water scarcity for bats, and provide resources and funding toward WNS recovery efforts. On the regional level, the Southeastern Bat Diversity Network (SBDN) helps to conserve bats and their habitats as well as facilitate education, research, and management in the Southeast. This working group is composed of bat biologists, land managers and others from 16 southeastern states seeking to facilitate communication, identify bat conservation priorities, and implement conservation programs regionally. Together, BCI and SBDN created the Conservation Strategy for Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*) and Southeastern Myotis (*Myotis austroriparius*) (BCI and SBDN 2013)

Chapter 2: Natural History and Habitat Requirements

Natural History

Reproduction and Longevity

Though there is often very little courtship behavior involved in the mating of bats, male and females in North America often gather in swarms at the entrance of hibernacula or autumn roosts to mate between late summer and early winter (Barbour and Davis 1969, Thomas et al. 1979). However, mating may also occur within hibernacula during periods of arousal from hibernation in some species. Delayed ovulation and fertilization are common reproductive methods used by bats, and occur when sperm is stored in the oviduct over winter and the egg is fertilized in late winter or early spring. One of the exceptions to this is the Brazilian free-tailed bat, which does not store sperm over winter but mates in mid-Feb to late March. Gestation for about half the bats in South Carolina lasts between 40 and 60 days and 20 to 30 days longer for the Brazilian free-tailed bat, Rafinesque's big-eared bat, eastern red bat, hoary bat, and Seminole bat.

The number of young produced by bat species of South Carolina varies from one to five, though most species have an average of two per year. However, all *Myotis* species in the state except for the southeastern bat give birth to one young per year. Most bats in South Carolina are born between May and June. Even though silver-haired bats are a migrant and may give birth in more northern portions of their range, there are records of silver-haired bats in the northwest corner of South Carolina in April and July (Webster 2013). Any parturition in those areas would be expected in June and July.

Newborn bats are completely dependent on their mother for care, and are naked and pink-skinned (Kunz and Kunz 1987). Young are generally left in a nursery roost, often in a crèche with other young, while the mother forages. For five bat species of South Carolina where the duration is known, lactation generally lasts between four to six weeks. Most young usually become volant (able to fly on their own) between three to five weeks, and in six species are weaned between three to nine weeks. For most species in South Carolina, males and females usually become sexually mature within their first year of life.

The bats found in South Carolina have a life span that varies by species from an average of two years in the evening bat to a maximum of 30 years in the little brown bat. This is particularly amazing because, for example, most small rodents the size of the eastern small-footed bat only live around 1.5 years while the eastern small-footed bat may live up to eight times longer. Accurate survival rates on most species of bats in the state are unknown. As is true for many animals, the survival rates in North American bats have been shown to be higher in adults at 63-90% than in juveniles at 23-80% (Tuttle and Stevenson 1982, Frick et al. 2007, 2010*b*, O'Shea et al. 2010, 2011).

Echolocation

Echolocation is a highly evolved process whereby a bat emits an ultrasonic sound and processes the echo from that sound in order to identify objects in its immediate environment. This ability is what allows bats "see" in total darkness, though bats are not blind and many have excellent vision. The ultrasonic sounds used are created as air passes over the vocal cords in the larynx, and then emitted through the mouth or nostrils at frequencies between 20 kHz and 120kHz. These high frequency sounds are above the range of human hearing, and have relatively short wavelengths that serve to best detect small prey items. Additionally, because short wavelengths don't travel far, it may help bats avoid interference from the echolocation of other bats. Bats have large, highly adapted ears that allow them to hear returning echoes from high frequency sounds bouncing off objects such as insects in their environment. Just inside and at the base of their ear is a cartilaginous projection known as the tragus that may help to improve the directionality or sensitivity to incoming echoes (Altringham 2011). In general, bats use echolocation to track the movements of prey by emitting short pulses of sound separated by longer periods of silence, processing the echoes returned to them, determining the distance to their prey, and emitting more pulses of sound to track and eventually capture their prey (Arita and Fenton 1997). More specifically, there are different phases associated with prey capture whereby bats change the length, absolute frequency and bandwidth (range of frequencies) of their pulses. When a bat is looking for prey during the search phase, their sound pulses are longer, have more time in between each pulse, and may be emitted at lower frequencies in order to travel further and cover a larger search area. When prey is detected, the approach phase occurs, whereby the bandwidth of the pulses increases and become faster and shorter together to avoid overlap as the bat approaches its target. During the last or terminal phase, the pulses become even faster, shorter, and higher in frequency, which provides more detail to the exact location of the prey right before capture.

The variation in these echolocation calls during the prey capturing process is split into two broad categories: frequency modulated (FM) calls with broadband components and constant frequency (CF) calls with narrowband components. Broadband FM pulses are characterized by short pulses that steeply sweep down frequencies, such as from 60 to 30 kHz within a few milliseconds in vespertilionids (Altringham 2011), or most South Carolina bat species. This steep sweeping or modulation is why they are referred to as frequency modulated calls, and they are used to detect nearby objects and are more accurate for localizing objects or prey. Narrowband CF calls are characterized by long pulses with a constant frequency, and are best used for detection of prey or objects further away. Because both calls are useful for different purposes, most bats use a combination of the two (Altringham 2011).

Different species of bats have a different acoustic structure to their echolocation calls, which can be a useful tool in the identification of a species (O'Farrell et al. 1999). However, the absolute frequency, harmonic structure, bandwidth, duration, and intensity all vary not only across species but also within them, which may occur due to different populations and habitat types (Neuweiler 1989, Fenton 1990, Barclay 1999). For example, in some species call features are distinct enough for the determination of that species to be fairly clear, but for other species there is too much overlap to tell. Recently however, there has been a shift from the focus on the time and frequency of calls for bat identification (referred to as zero-cross methodology) toward a technology that analyzes the full spectrum of the call in order to recognize additional characteristics specific to each species. This full-spectrum methodology is thought to increase robustness, accuracy, and confidence of identification. Specific bat detector and software programs are required depending on the methodology chosen to identify bat vocalizations. Recordings from both zero-cross and full-spectrum sampling require filtering and edits within bat identification software, and the calls identified may still need to be visually confirmed due to call similarities between species.

Foraging Behavior and Diet

Foraging Behavior

All of South Carolina's bats are insectivorous, and capture prey either during flight or by gleaning them from the surface of water, foliage, and even the ground (Hill and Smith 1984). Foraging bouts usually start in the first few hours after sunset, with activity slowing as individuals rest at night roots and increasing again a few hours before sunrise. However, emergence time and length of foraging bouts for adult females may differ depending on their reproductive stage and number of pups (Barclay 1989). Foraging behavior may include establishing foraging territories, as in the case of the hoary bat (Barclay 1984).

Foraging behavior varies within South Carolina bats, and is closely related to echolocation characteristics and morphology associated with each species. As previously mentioned, bats have differing acoustic structures within their echolocation calls. These echolocation characteristics are strongly related to differing foraging strategies: species that fly in cluttered habitats tend to use calls that quickly detect close objects, and species that fly in open habitats use calls that detect distant objects. To do this, lower intensity, shorter duration, higher peak frequency and a broader range of frequencies such as broadband FM calls are more often used by species that forage in dense vegetation. Higher intensity, longer duration, lower peak frequency with a narrower range of frequencies such as narrowband CF calls are more often used by bats that feed in more open areas (Schnitzler and Kalko 1998, Lacki et al. 2007). Additionally, species that glean insects off of foliage or the ground rely more on vision and hearing in order to detect their prey (Bell 1985, Faure and Barclay 1992).

Wing morphology characteristics are a major indicator of whether bat species tend to be slow and maneuverable in cluttered habitats with the ability to hover and glean insects from foliage, or perhaps specialize in fast flight and open-air hawking in uncluttered areas. These behaviors are often related to two major components of wing morphology: aspect ratio and wing loading. The aspect ratio (AR) can be calculated as the square of the wingspan length divided by the surface area of the wing (also calculated as the wing length divided the length of the fifth phalanx). A low aspect ratio generally indicates that a species has short, broad wings, which is often associated with bats that hunt insects among vegetation and have good maneuverability at low flight speeds (Norberg and Rayner 1987). On the other hand, a high aspect ratio generally indicates long, narrow wings, often associated with bats that prey on high-flying insects at high flight speeds (Norberg and Rayner 1987). Wing loading (WL) is determined by dividing the mass of the bat by its total wing area (also calculated by dividing the mass by the wing length times the length of the fifth phalanx). Low wing loading generally indicates a small bat with relatively large wings and slow flight, and high wing loading tends to indicate a large bat with relatively small wings and fast flight. However, these general statements are not always true as specific hunting patterns may vary over an evening. For example, little brown bats are known to initially feed along margins of lakes and streams and in and out of vegetation, and later in the evening forage over the surface of water in groups (Fenton and Bell 1979).

High WL is often found in combination with high AR, and indicates a fast, long-distance migrator that catches insects on the wing in open areas. Two species found in South Carolina that fit these characteristics are the Brazilian free-tailed bat and the hoary bat (Figure 5, colored in red). Even though the Brazilian free-tailed bat is a migrator in other portions of its range, it is a resident to South Carolina. In comparison, low WL and low AR indicate species with slow flight and high maneuverability that feed among vegetation and are generally known as clutter-adapted species. All of the *Myotis* species of South Carolina (eastern small-footed bat, little brown bat, northern long-eared bat, and southeastern bat), as well as the tricolored bat and Rafinesque's big-eared bat, tend to fall into this category (Figure 4, colored in green). Eastern red and Seminole bats have also been considered a clutter-adapted species, however, the activity of tricolored bats, eastern red bats, and Seminole bats did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005).

Two similar categories have species with somewhat long, pointy wings (though less so than the Brazilian free-tailed and hoary bats), and include the single *Lasionycteris* species and the rest of the *Lasiurus* found in South Carolina. These relatively pointy wings are good for either efficient flying in open areas, migration in more northerly portions of their range (though the majority in these categories are residents to South Carolina), or long-distance migration as in the case of the *Lasionycteris* species, or silver-haired bat. The faster flying category of these includes the northern yellow bat (Figure 5, colored in yellow), while the eastern red bat, Seminole bat, and silver-haired bat fly at relatively slower speeds (Figure 5, colored in blue). Many of these species are known to forage at or above treetop level, in open areas, over water, and in the case of the silver-haired bat, also along intact riparian areas and in or near coniferous and/or mixed deciduous forests (Kunz 1982*a*).

The big brown bat does not have particularly long or pointed wings, but is still considered a fast flier (Figure 5, colored in purple). This species has been known to forage among tree foliage instead of above or below the forest canopy (Schmidly 1991). Even though big brown bats have been recorded as flying above forest canopy in South Carolina (Menzel et al. 2005*b*), they are still readily captured below the canopy. The evening bat has intermediate wing shape and speed relative to other bat species in the state (Figure 5, colored in black), and despite its general classification as a clutter-adapted species, tends to forage above the forest canopy, in forest gaps, clear cuts, young tree stands, or over water in South Carolina (Menzel et al. 2001*a*, 2005*b*, M. A. Menzel et al. 2003).

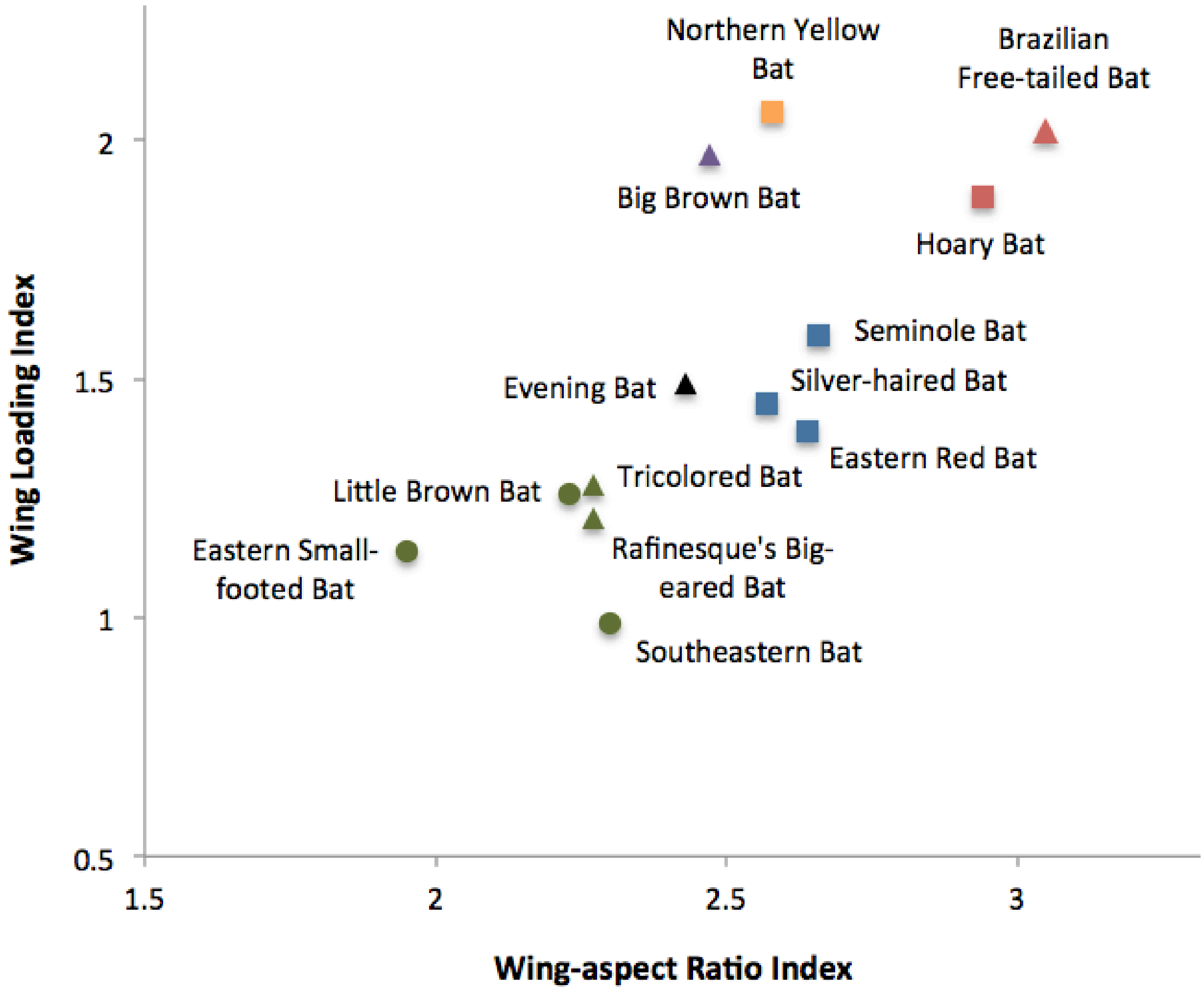


Figure 5: Wing loading and aspect ratios of southeastern bats. All calculations from bats captured at the Savannah River Site by M. A. Menzel et al. (2003) except eastern small-footed bat which came from Johnson et al. (2009). No information was provided for northern long-eared bat. Circles = colonial roosting *Myotis* species; Triangles = other colonial roosting species; Squares = foliage roosting *Lasiurus* and *Lasionycteris* species; Green = shortest, broadest wings and slowest speed; Red = longest, narrowest wings and fastest speed; Yellow = longer, narrower wings and faster speed; Blue = longer, narrower wings and slower speed; Purple = intermediate wing shape and faster speed; Black = intermediate wing shape and intermediate speed.

Diet

In the southeastern US, at least 12 dietary studies of bats have been conducted. Nearly half of those were in Florida (Sherman 1935, 1939, Jennings 1958, Zinn 1977, Zinn and Humphrey 1981), four in South Carolina (Armbruster 2003, Carter 1998/Carter et al. 2004, Donahue 1998, Menzel et al. 2002*a*), and two in Georgia (Carter et al. 1998, Menzel et al. 2000*b*). South Carolina's bats probably eat enough arthropods and insects to equal up to half or more of their body weight in one evening (Hill and Smith 1984, Kurta et al. 1989*a*, 1990, Kunz et al. 1995). Like most North American bats, the species found in the state are nearly all prey generalists and opportunistically feed on multiple insect orders (Lacki et al. 2007), though Rafinesque's big-eared bat shows moderate dietary specialization for Lepidoptera, and to a lesser extent so do hoary bats and the silver-haired bats. The top four most widely consumed prey groups of bat species known to occur in South Carolina are Lepidoptera, Coleoptera, Diptera, and Hymenoptera. The rest of the orders and suborders consumed by these species, along with examples of insect types within each, are listed in Table 3. However, diet studies in South Carolina have been conducted on only four species of bats, including the eastern red bat, evening bat, and Seminole bat (Carter 1998/Carter et al. 2004), as well as Rafinesque's big-eared bat (Armbruster 2003). Diet studies in the southeast have been conducted on four additional species, and include the tricolored bat, big brown bat, and northern yellow bat (Carter et al. 1998), as well as the southeastern bat (Zinn and Humphrey 1981). However, a recent PhD position with Clemson University will include research on stable isotopes and DNA analysis of bat fecal pellets in the eastern US.

Table 3: Orders and suborders of insects consumed by bat species in South Carolina

Order or *Suborder*	Insects
Araneae	Spiders
Coleoptera	Beetles
Diptera	True flies, mosquitos, midges, gnats
Ephemeroptera	Mayflies
Hemiptera	True bugs
Heteroptera	Lygaeid bugs, waterbugs, bedbugs, stinkbugs, leaf-footed bug, shield bugs
Homoptera	Cicadas, aphids, leafhoppers, froghoppers, spittlebugs
Hymenoptera	Bees, ants, wasps
Isoptera	Termites
Lepidoptera	Moths, butterflies
Neuroptera	Lacewings
Orthoptera	Grasshoppers, crickets, locusts
Odonata	Dragonflies
Zygotera	Damselflies
Plecoptera	Stoneflies
Trichoptera	Caddisflies

Torpor

Torpor is a process whereby body temperature, oxygen consumption, and blood flow are reduced in a controlled manner in order to budget for periods of inactivity, and is an important life history strategy in bats (Altringham 2011). Bats may use daily torpor over a period of a few hours to conserve energy on a daily basis, and it is normally used in the active or warmer months of the year. The point at which torpor is considered hibernation is difficult to define, and depends on food, temperature and other demands. Generally however, hibernation is a deep torpor with greater declines in body temperature and metabolic rate for long periods of time such as days, weeks or months, and occurs seasonally in response to food reduction instead of declining temperatures (Geiser 2010, Altringham 2011). Bats do not remain in continuous torpor even during hibernation, and have the ability to wake spontaneously and independently of ambient temperature. Additionally, they may wake either spontaneously or from external factors. For example, little brown bats during summer torpor wake from stimulation of external factors, but while hibernating spontaneously arouse from torpor (Menaker 1961).

Bats save enormous amounts of energy with the use of torpor, either during unproductive foraging conditions or in habitats that would otherwise be too cold or harsh for survival (Bell et al. 1986, Chruszcz and Barclay 2002, Rambaldini and Brigham 2008). Some species, such as the eastern red bat, may become torpid at temperatures below 69°F (20°C) or 48°F (9°C) and survive subfreezing temperatures by maintaining body temperature just above the critical limit of

23°F (-5°C) (Reite and Davis 1966, Padgett and Rose 1991, Whitaker et al. 1997).

Especially in the coastal regions, the mild winter conditions in South Carolina allow for many species of bats to use daily torpor and forage on warm nights when insects are available, and use intermittent, shallow hibernation only on particularly cold nights.

Daily torpor

The frequency of daily torpor varies depending on weather, food availability, season, sex, and reproductive condition, and is used by bats any time it's beneficial (Grinevitch et al. 1995, Geiser 2004, Klug and Barclay 2013). Additionally, the use of daily torpor may be used less by reproductive females than nonreproductive females and males. Reproductive females need to maintain high body temperature and speed the growth of the developing fetus (Kunz 1987, Kurta and Kunz 1988). However, these females may use torpor more often or for longer periods when pregnant than when nursing. This may be because the female isn't hindered by the weight of the fetus, and the fact that it is later in the year when warmer temperatures and higher food availability exist (Audet and Fenton 1988, Grinevitch et al. 1995, Chruszcz and Barclay 2002, Lausen and Barclay 2006, Willis 2006). Waking from daily torpor is energetically expensive, so males and nonreproductive females may seek cooler roosts during the morning to use deeper daily torpor more efficiently, and warmer roosts later in the day to assist in passive rewarming before arousing to forage in the evening (Hamilton and Barclay 1994, Willis 2006, Rambaldini and Brigham 2008).

Half of the bat species in South Carolina, including the northern long-eared bat which is considered a true hibernator, may wake from torpor to forage during warm winter nights. These include the big brown bat (Mumford 1958), Brazilian free-tailed bat (Barbour and Davis 1969, Lowery 1974, Wilkins 1989), eastern red bat (Padgett and Rose 1991, Whitaker et al. 1997), the northern long-eared bat (Whitaker and Rissler 1992*a*, Whitaker and Mumford 2009), northern yellow bat (Jennings 1958), Seminole bat (Wilkins 1987), and silver-haired bat (Humphrey 1975, Nagorsen and Brigham 1993, Dunbar 2007, Falxa 2007). Many of the other species in the state are known to be active year round and only enter torpor when the weather is extremely cold, such as Rafinesque's big-eared bat (Jones and Suttkus 1975, Ferrara and Leberg 2005). Also, Brazilian free-tailed bats may cluster together in groups to keep warm as the temperature decreases (Pagels 1975).

Hibernation

Hibernation usually lasts from three to seven months in North American bats, beginning around October and lasting through March or April. For species in South Carolina, the earliest bats to arrive at hibernacula and the last to leave are tricolored bats, who generally roost in hibernacula from late July through October and disperse in early April (Griffin 1940, Fujita and Kunz 1984, Schmidly 1991). At the other end of the spectrum is the eastern small-footed bat, which is one of the last to enter and one of the first to leave hibernacula, seldom entering before mid-November (Godin 1977, Gunier and Elder 1973,) and departing by early March (Mohr 1936).

Hibernation is generally entered with fat reserves of between 20 to 30 % of the body weight of the bat (Altringham 2011). This holds true for most hibernating bat species occurring in South Carolina except for the northern long-eared bat who is known to lose up to 45% of its body weight during winter in the northern portions of its range (Caire et al.

1979, Caceres and Barclay 2000). Additionally, female bats generally enter hibernacula at a higher weight than males (Ransome 1971). Bats may arouse from hibernation in order to seek suitable temperatures, avoid disturbance, enhance immune function, obtain water, mate, or forage outside the hibernacula (Ransome 1990, Thomas and Geiser 1997, Luis and Hudson 2006, Altringham 2011). Many species in North America often do not leave the hibernacula but resume torpor shortly after waking, which is true for obligate hibernators in South Carolina such as the tricolored bat (Whitaker and Rissler 1992*b*, Briggler and Prather 2003). This species also tends to stay in deep torpor for the longest periods of time than other temperate hibernating bats (maximum recorded at 11 days) (Twente et al. 1985, Amelon 2006).

Roosting Behavior

There are many important potential benefits provided by roosts for bats. These include protection from weather and predators, more efficient thermoregulation, shorter commuting distances to foraging sties, improved mating opportunities and maternal care, information transfer, and competition avoidance (Altringham 2011). Roosting behavior may differ depending on the abundance and dispersion of food, species, season, reproductive stage, sex, human disturbance, and proximity to foraging sites and water. Also, there are some common themes among bats and their roosts. For example, bats using stable roosts such as caves are frequently faithful to these sites over years and generations, and those that roost in foliage may have increased local movements but still be faithful to a particular location (Altringham 2011). There are four main types of roosts, categorized as day roosts, night roosts, maternity roosts, and hibernacula.

Day roosts and night roosts

A day roost is a roost used by bats during daylight hours where they spend the non-active part of the day resting or in torpor. Bat species occurring in South Carolina roost in a variety of structures typically including caves, mines, tunnels, rock crevices, tree foliage, beneath loose bark, tree cavities, buildings, bridges, and artificial bat roosts such as bat houses and bat towers. Species of bats in the *Lasiurus* genus, or the tree roosting bats, typically roost solitarily in tree foliage, tree cavities, and even Spanish moss in the case of the northern yellow bat and Seminole bat, but may also use woodpecker cavities (Fassler 1975), leaf litter (Moorman et al. 1999), dense grass (Mager and Nelson 2001), or grooves of palm trees (Davis 1974). Colonial roosting bats (including all *Myotis* species and others) typically roost in groups in caves, mines, tunnels, buildings, bridges, artificial roosts, and beneath tree bark, depending on the season and reproductive stage of the bat. As bats move between summer and winter roosts, short term day roosts may be referred to as a transient or interim roost, while migratory species moving between seasonal ranges may use migratory roosts.

A night roost is a temporary, short-term roost used by bats nocturnally to rest between foraging bouts, digest prey, escape predators, and find shelter from weather. These roosts are often associated with higher than ambient temperature, which is thought to aid in the conservation of energy as well as maintain higher metabolism needed for digestion (Buchler 1975, Fenton and Barclay 1980). Not much is known about night roosts used specifically in South Carolina. Elsewhere however, garages, breezeways, picnic shelters, and house porches are commonly used as night roosts for big brown bats (Harvey et al. 2011), ceilings of caves are used by eastern small-footed bats (Davis et al.

1965), different locations in the same buildings are used as day roosts by little brown bats (Barclay 1982), caves, mines, and quarry tunnels that differ from day roosts are used by northern long-eared bats (Jones et al. 1967, Clark et al. 1987), and caves, mines, and rock crevices are used by tricolored bats (Barbour and Davis 1969). Some species may not use night roosts at all if they tend to forage throughout the night, such as the Brazilian free-tailed bat (Whitaker and Hamilton 1998).

Maternity roosts

During spring and summer, most bats segregate by sex and reproductive status. Breeding females of foliage roosting bats generally rear young in tree foliage without a maternity colony, and colonial roosting bats gather in a maternity roost to rear young. Maternity roosts are often associated with higher than ambient temperature, which is thought to aid in maintaining higher metabolism needed for lactation and promoting fetal development and growth of the young. The temperatures required vary depending on species, but are usually between 70°F (21°C) and 90°F (32° C) (Tuttle and Taylor 1998). These warmer temperatures may be due to the location of the colony and/or the large numbers of individuals within the colony. The size of maternity colonies in South Carolina vary from five to a few hundred, and may be found in buildings, picnic shelters, attics, cavities of trees, under tree bark, and in artificial roosts. Maternity colonies of at least five species have been found in South Carolina, including big brown bats (Carter 1998, Menzel 1998), evening bats (Menzel et al. 2001*a*, Hein 2008), tricolored bats (Menzel et al. 1996), little brown bats (Loeb and O'Keefe 2006), and Rafinesque's big-eared bats (Bennett et al. 2003*b*, M. A. Menzel et al. 2003, National Park Service 2004). In the southeast, pup mortality events have been noted in big brown bats, and occasionally Brazilian free-tailed bats, in extremely hot weather in June or July.

Hibernacula and other winter roosts

Hibernacula are roosts used by bats during colder months such as in late fall, winter, and early spring. Bats enter torpor and hibernate during this time, and can survive by utilizing fat stores gained during the summer months. Types of hibernacula often occupied by bats in South Carolina include caves, mines, tunnels, rock crevices, buildings, and tree hollows. The temperatures within winter roosts are generally between 34°F (1°C) and 50°F (10°C), and hibernacula that have varying temperature regimes are beneficial to bats as it allows them to find suitable temperatures regardless of winter weather (Tuttle and Taylor 1998). However, bat species found in milder coastal areas may use hibernacula with temperatures of 59°F (15°C) or more (Webb et al. 1996). Besides temperature, humidity is an important factor in the selection of hibernacula. For example, little brown bats (Fenton 1970, Humphrey and Cope 1976, Nagorsen and Brigham 1993) and northern long-eared bats (Fitch and Shump 1979, Whitaker and Mumford 2009) are usually found in caves with high levels of humidity, sometimes from 70-95 %. High humidity is thought to help prevent dehydration in roosting bats since it reduces the amount of water lost to the air (Altringham 2011). Where there is information, many bat species in South Carolina hibernate singly or in small groups. The exceptions are the tricolored bat that is consistently found hibernating in groups of a few hundred individuals in South Carolina (but not in clusters, where individuals touch), and Rafinesque's big-eared bats that may hibernate together in clusters. For many species that hibernate in groups, males and females hibernate together. Hibernacula of at least seven species have been found in South Carolina, including the tricolored bat in abandoned mines and incomplete Blue Ridge Railroad tunnels in the mountains (Bunch et al. 2015*b*), little brown bats in caves and tunnels in Pickens County (Bunch et al. 2015*b*), eastern small-footed bats in a rock outcrop crevice in mature hardwoods in the mountains of Pickens County (Bunch and Dye 1999*a*), evening bats in Charleston County attics (M. A. Menzel et al. 2003), northern long-eared bats in a cave and single individuals in tunnels (Bunch et al. 1998*a*, Bunch 2011), Rafinesque's big-eared bats in a gold mine in Oconee County and abandoned buildings in Aiken County, and southeastern bats in cave system in Orangeburg County (J. M. Menzel et al. 2003).

Roost site fidelity and roost switching

Fidelity to roost sites depends on species-specific factors including sex, age, reproductive status, and social organization of bats, temporal factors such as season, and various environmental factors such as roost permanence and availability, disturbance, predation, parasites, and availability of food (Lewis 1995). For example, during summer some species may have high fidelity to maternal roosts, while during winter some may have high fidelity to hibernacula.

South Carolina bat species such as big brown bats (Davis 1967, Brenner 1968, Mills et al. 1975) have high fidelity to maternal roosts, and eastern small-footed bats (Gates et al. 1984), northern long-eared bats (Griffin 1945, Mills 1971, Caire et al. 1979), and tricolored bats (Hahn 1908, Menzel et al. 1999*a*) have high fidelity to hibernacula. Rafinesque's big-eared bats and foliage roosting bats such as eastern red bats and Seminole bats generally switch roosts frequently and do not have high fidelity to particular roosts, but may have high fidelity to certain areas or sites (Hutchinson 1998, Menzel et al. 1998, Mager and Nelson 2001). Frequent roost switching may be a response to changing microclimate conditions at different trees (Hoffmeister and Goodpaster 1963, McNab 1974, Jones and Suttkus 1975, Kunz 1982*b*). For example, roost switching is relatively rare for undisturbed Rafinesque's bats living in buildings (Clark 1990). For species with low fidelity to particular roosts but high site fidelity, stand and landscape features may be influence roost-site selection more than tree and plot characteristics (Lunney et al. 1988, Cryan et al. 2001, Elmore et al. 2004).

Movements and Migration

Nightly and seasonal movements

Most North American bats don't move long distances between day roost and foraging habitat (around 0.3 to 6 miles, or 0.5 to 10 km), and this holds true for many bat species that occur in South Carolina. Mostly in other states, distances from day roosts to foraging areas have been recorded at 0.62 to 1.24 miles (1 to 2 km) for big brown bats (Brigham 1991), 1,600 to 3,000 feet (500 to 900 m) for eastern red bats (Jackson 1961), 0.6 to 9 miles (1 to 14 km) for little brown bats (Henry et al. 2002), 2,000 feet (602 m) from maternity roosts for northern long-eared bats (Sasse and Pekins 1996), 358 feet (109 m) for a northern yellow bat (Krishon et al. 1997), and 0.62 miles (1 km) for Rafinesque's big-eared bats (Menzel et al. 2001*c*). The exception to short distances moved between day roost and foraging habitat is the Brazilian free-tailed bat that typically moves up to 50 miles (80 km) (Whitaker et al. 1980). For reproductive females, these distances may be shorter to more efficiently visit the maternity roost multiple times in a night.

Most bat species in South Carolina are considered nonmigratory, yet may have small seasonal movements. According to studies in other states, movement from summer roosts to hibernacula is less than 56 miles (90 km) in big brown bats (Mills et al. 1975, Neubaum et al. 2006), 0.06 to 0.68 miles (0.1 to 1.1 km) in eastern small-footed bats (Johnson and Gates 2008), 35 miles (56 km) in northern long-eared bats (Caire et al. 1979), 2.1 miles (3.4 km) in Rafinesque's big-eared bats (Finn 2000, Johnson and Lacki 2011), and 18 to 45 miles (29 to 72 km) in southeastern bats (Rice 1957). Some species, such as the Brazilian free-tailed bat, eastern red bat, hoary bat, and tricolored bat are migratory in the northern portions of their range, but are generally considered year round residents to South Carolina (M. A. Menzel et al. 2003). In the past, a Brazilian free-tailed bat colony was known to roost in an old church the Piedmont region of South Carolina during summer, but leave for the winter to an unknown location. The majority of hoary bats in South Carolina probably migrate north in spring as they are rare in the state during summer, but there is evidence that some are found here during that time (M. A. Menzel et al. 2003). For species such as the northern yellow bat, it is suspected but unknown if they are resident to the state.

Migrational movements

Long-distance migrants are known to move hundreds of miles across the continent, and long-distance migrants that occur in South Carolina are the hoary bat and the silver-haired bat (Cryan 2003). As mentioned above, the hoary bat may be resident to the state. However, silver-haired bats are migratory to South Carolina as they are over much of their range. This is thought to shift to the north in the spring and to the south in the fall, though the southern shift appears to be more extensive in eastern than western North America (Baker 1978, Izor 1979). Females migrate further than males, and males are only present throughout the range during migration (Kunz 1982*a*). The timing of fall migration for this species generally occurs in two waves, primarily from August through September (Barclay 1984, Arnett et al. 2008, McGuire et al. 2012). In eastern North America, McGuire et al. (2012) predicted the fall migration rate of silver-haired bats from the north side of Lake Erie to the southeastern US be 155 to 170 miles (250 to 275 km) per night for five to six nights without refueling, even though brief stopovers of one to two days do occur. However, migrating individuals do engage in feeding activity, especially on non-travel nights (Reimer et al. 2010, McGuire et al. 2012). Spring migration also happens in waves, and occurs along the southern shore of Lake Manitoba in May and early June (Barclay et al. 1988). In South Carolina, silver-haired bats are distributed statewide, but during summer they are not generally found in the lower Piedmont or Coastal Plain due to their migratory patterns (M. A. Menzel et al. 2003, Bunch et al. 2015*a*), but are found in the northwest corner of the state in April and July (Webster 2013).

Little brown bats could be considered migratory because they may migrate several hundred miles between hibernacula and summer roosts in other states (Davis and Hitchcock 1965, Fenton 1970, Humphrey and Cope 1976), especially in the northeast (Schmidly 1991). However, it is unknown where most of South Carolina's summer populations of little brown bats spend the winter or how far they migrate (Bunch et al. 2015*b*).

Habitat Requirements

Roosting Habitat

Roosting habitat is extremely important in the daily lives of bats as they spend most of their lives in roosts. As mentioned in the section on roosting behavior, categories of roosts include day roosts, night roosts, maternity roosts, and hibernacula. Within each of these categories are specific types such as caves and mines, rock crevices, buildings, bridges, trees, and artificial bat roosts that will be covered in detail in this section. Types of roosting habitats used by bat species occurring in South Carolina can be found in Table 4.

Understanding how and where bats roost provides key facts about their distribution, densities, seasonal movements, social structure, and foraging and mating strategies. Knowing which roosts bats have high fidelity to is important conservation information, since these sites are critical for raising young, maintaining social contacts, and offering suitable conditions for hibernation (Kunz 1982*b*, Lewis 1995). Roost selection research has provided useful information for small-scale characteristics of bat roosts, but it is important to keep in mind that for many bat species such as tree roosting bats, stand and landscape scales may be of equal or greater importance (Lunney et al. 1988, Cryan et al. 2001, Elmore et al. 2004, Miles et al. 2006). Additionally, it is possible that roost sites selected may differ based on landscape conditions. For example, day roosts selected in Georgia on a natural site were based on tree, plot, and landscape characteristics, but on the managed site they were selected at the tree and plot scale (Miles et al. 2006). In this case, less roosting structures over the landscape were probably available due to the young forest stand age of the managed areas. Finally, other potentially limiting landscape features like nearby foraging areas and water resources may also play a part in roost selection by bats.

Table 4: Roost types used by bat species known to occur in South Carolina. Modified from Menzel et al. (2003).

	Roost Type							
Common Name	Cave or Mine	Foliage	Spanish Moss	Tree Bark or Cavity	Cliffs, Talus, or Rock Crevices	Artificial Structure	Bird/Squirrel Nest	Leaf Litter
Big Brown Bat	WS			WS	S*	WS	S*	
Brazilian Free-tailed Bat				W* S*		WS		
Eastern Red Bat		WS	WS*	S*		S	W* S*	W
Eastern Small-footed Bat	WS*			S*	S	S		
Evening Bat		S	S*	S		WS		
Hoary Bat		WS	W*	W* S*			W*	
Little Brown Bat	WS			S	S*	S		
Northern Long-eared Bat	WS*			S	W*	WS		
Northern Yellow Bat		WS	WS					
Rafinesque's Big-eared Bat	WS			WS	WS	WS		
Seminole Bat		WS	WS	WS				W
Silver-haired Bat	W	S*		WS	W* S	W	S*	
Southeastern Bat	WS			WS		WS		
Tricolored Bat	WS	S		S		WS		

W = winter roost; S = summer roost; * = Not necessarily observed/common in South Carolina, but possible

Caves, mines, and tunnels

Caves and mines are the most stable and persistent roosts, and the most often used during winter for hibernation. Otherwise, they may be used as night roosts, transient roosts, or a place to raise young (Barbour and Davis 1969, van Zyll de Jong 1985). Nine of the 14 species in South Carolina use caves, mines, or tunnels at some point during the year (Table 4). Tricolored bats are often the largest populations of bats found in these types of roosts in the state (Bunch et al. 2015*b*).

For a cave or mine to be suitable for bats, the microclimate needs to have just the right conditions for the differing stages of a bat's life cycle (Tuttle and Taylor 1998). Airflow, air temperature, and humidity are environmental factors important to suitable cave site selection, which are influenced by the season as well as the size, configuration, and complexity of the cave (Tuttle and Taylor 1998, Sherwin et al. 2009, Altringham 2011). However, there are only two well-known caves in South Carolina, one located in the Blue Ridge region and the other in Orangeburg County in the Coastal Plain.

Because South Carolina doesn't have many caves, similar roosts such as mines, abandoned tunnels, and old bunkers are especially important to bats in the state. Over 200 known or potential mine locations have been mapped by SCDNR, most of which are mines or prospects in the Piedmont region that were placer mines with no adits or shafts, and thus provided no underground bat roosts. However, of the 58 surveyed that had potential for bat roosts, nine had an underground component with tricolored bats present. South Carolina also harbors abandoned tunnels in the Blue Ridge region and old bunkers in the Piedmont region. Two major hibernacula for tricolored bats exist in the incomplete Blue Ridge Railroad tunnels. The Stumphouse Mountain Tunnel is owned by Clemson University and managed by the city of Walhalla, and the Middle Tunnel has a bat friendly entrance gate and is owned and managed by SCDNR as part of the Stumphouse Mountain Heritage Preserve. Six World War II bunkers at SCARNG McCrady Training Center near Columbia, SC provide important hibernacula and roosting habitat for various bat species in the state including big brown bats and Rafinesque's big-eared bats.

Cliffs, talus, and rock crevices

Cliffs, talus or rock crevices may be used during various seasons by bat species in South Carolina. The bat species commonly known to use these roosts are eastern small-footed bats and Rafinesque's big-eared bats, though big brown bats, little brown bats, northern long-eared bats, and silver-haired bats may also do so occasionally (Table 4). Rafinesque's big-eared bats have been found in a rock cliff area on Duke Energy owned property at the Bad Creek, Whitewater River research area (J. M. Menzel et al. 2003). Factors important to selection by bats of suitable sites include protection from predators, temperature, and proximity to water sources and foraging areas, though rock crevices rarely offer the same protection or thermal stability as caves (Rancourt et al. 2005, Altringham 2011). However, very little research has been conducted on these types of roost sites due to the difficulty of detecting bats within them. Species that use these sites often roost singly or in small groups, tuck themselves deeply within crevices, and, as in the case of eastern small-footed bats, are also very small.

Buildings and bridges

Buildings and bridges may be used as hibernacula, maternity roosts, and substitutes for other natural roost types used in the past.

In fact, a few bat species have benefited from these types of artificial roosts through populations increases and growing distributions (Kunz and Reynolds 2004). For example, buildings are considered the most important hibernacula for big brown bats in northwestern US (Nagorsen and Brigham 1993, Maser 1998).

Buildings used by bats commonly include houses, garages, barns, churches, cabins, and picnic shelters, and may be used as day roosts, night roosts, maternity roosts, or hibernacula. They may either roost inside, such as in an attic or a chimney, or on external portions of a building such as underneath wooden shingles, shutters, wooden siding, eves and porches. The gaps in a building's exterior don't need to be very large for a bat to enter, and can be as narrow as 0.4 inches (9.5 mm) or a hole as small as 0.7 inches (1.8 cm) across (Greenhall 1982). Older or abandoned buildings with many entry points are often a preferred roost, especially when coupled with the lack of human disturbance. Bat species in South Carolina most commonly found in buildings are the big brown bat, Brazilian free-tailed bat, evening bat, and tricolored bat. Less commonly found are little brown bats in buildings and picnic shelters at the SCDNR Fish Hatchery in Oconee County (Bunch et al. 2015*b*), and eastern small-footed bats in a woodpile on a porch, a fish hatchery building, a picnic shelter, and under loose tarpaper of an abandoned log cabin (Bunch and Dye 1999*a*, Bunch et al. 2015*b*). Eastern red bats are sometimes found in shingles of houses, and evening bats, northern long-eared bats, and silver-haired bats are thought to use houses as winter roosts. Maternity colonies of evening bats, northern long-eared bats, Rafinesque's big-eared bats, and southeastern bats could be found in buildings as well.

Bridges, especially large concrete ones, may be used as day roosts, night roosts, maternity roosts, or hibernacula (Keeley and Tuttle 1999). Wooden and metal bridges without concrete joints don't seem to be used as often as concrete bridges, potentially because of the less stable thermal environment of metal bridges or the pungent odor caused by creosote that often coats wooden bridges. Concrete bridges provide a more thermally stable environment, as during the day they provide cooler temperatures and at night provide warmer temperatures than ambient air (Keeley and Tuttle 1999). Usually, locations on bridges used by bats are in expansion joints, corners located between beams, and other crevices. Bat species in South Carolina that use bridges include big brown bats, Brazilian free-tailed bats, eastern small-footed bats, Rafinesque's big-eared bats, southeastern bats and tricolored bats. All of these species except tricolored bats are known to use bridges as maternity roosts, though big brown bats, Rafinesque's big-eared bats, and southeastern bats may also use bridges as winter roosts. In a South Carolina study by Bennett et al. (2008) from May to August, Rafinesque's big-eared bats selected large, concrete T-beam and I-beam girder bridges as day roosts and avoided flat-bottomed slab bridges. These were used as either solitary or maternity roosts, though most of the occupied bridges were in the Upper and Lower Coastal Plains, with a few in the Piedmont region, and none in the Blue Ridge region.

Trees

Nine of the 14 bat species in South Carolina use trees for roosting during multiple seasons, and nearly all are known to use tree roosting sites at some point during the year (Table 4). Tree roosting sites may exist in the form of tree crevices, cavities, foliage, Spanish moss, palm fronds, squirrel nests, or woodpecker cavities. Overall, many bat species in North

America are known to select for higher roosts in larger trees within more open canopy and higher snag density (Menzel et al. 1998, Kalcounis-Ruppell et al. 2005), which may provide benefits such as easier roost access, protection from predators, and increased solar exposure for the growth of young (Racey and Swift 1981, Racey 1988, Vonhof and Barclay 1996). However, colonial cavity roosting bats tend to prefer more open canopies and be closer to water than foliage roosting bats (Kalcounis-Ruppell et al. 2005). The tree species chosen for roosts only seem to matter to bats when it comes to the characteristics and extent of decay that occur in that tree species. Factors of decay that provide suitable roost sites include the presence and amount of loose bark, trunk furrows, and either natural cavities or those constructed by woodpeckers. Additionally, early stages of decay may be selected for over rotten wood since more bark is generally retained and firm wood provides more effective insulation (Crampton and Barclay 1998). Since woodpeckers are the primary excavators of cavities used by bats, and these cavities are used by species such as the little brown bat, silver-haired bat, and big brown bat, understanding the abundance and excavation preference of woodpeckers and ultimately assist in bat conservation (Kalcounis and Hecker 1996, Mattson et al. 1996, Vonhof and Barclay 1996, Kalcounis and Brigham 1998). Generally, trees with decayed heartwood and relatively hard sapwood are preferred by woodpeckers (Harestad and Keisker 1989). Forest age and structure play an important role for many bats since they commonly roost in forests with higher snag densities and higher snag or live tree basal areas (Campbell et al. 1996, Cryan et al. 2001, Kalcounis-Ruppell et al. 2005). The closer tree roosts are to foraging and drinking areas, the less energy bats have to spend commuting. However, Barclay and Kurta (2007) found that access to other resources was not as important as the availability of suitable roost trees. The number of trees used by bats in eastern North America has been reported as one to six per bat and eight to 25 per colony for maternity colonies (Barclay and Kurta 2007).

Colonial roosting bats in the state are often found roosting under tree bark, using cavities, and may even be found in the foliage of trees as in the case of the tricolored bat during summer. Though big brown bats historically used loose bark and cavities of pine, oak, beech, bald cypress and other tree species, they now generally roost in human-made structures. However, in South Carolina they have been found using a hollow bald cypress for a maternity colony in a bottomland hardwood swamp (Carter 1998, Menzel 1998). Colony size of this species may depend on tree roost size as larger cavities of roost trees have been found to be correlated with larger numbers of reproductive female big brown bats (Willis et al. 2006). Brazilian free-tailed bats historically used the hollows of mangroves and cypress trees in the southeast (Jennings 1958), but like big brown bats, mainly use human-made structures today. Evening bats roost in hollow trees and under loose bark (Barbour and Davis 1969, Chapman and Chapman 1990, Menzel et al. 2001*a*), and have also been found in Spanish moss (Jennings 1958) and underneath palm fronds (Taylor and Lehman 1997). At the Savannah River Site in South Carolina, roosts were in cavities or under exfoliating bark and most commonly in longleaf pines (*Pinus palustris*), though conifer snags in beaver ponds were also common (Menzel et al. 2000*a*). In this study, compared to random plots, roosts were found in areas with taller and less dense canopy, greater snag abundance, the overstory had less trees and lower richness, and the understory had less trees, lower richness and lower diversity. In the lower Coastal Plain of South Carolina, evening bats roosted in cavities in hardwood trees and fork-topped loblolly pines (*Pinus taeda*), selecting roost sites in mixed-pine hardwoods (Hein 2008). Additionally, about 40% of male and 20% of female roosts were located in forested corridor stands. Evening bat maternity colonies in South Carolina used mature longleaf pine stands with a higher overstory, greater canopy density, and greater proportion of basal area composed of conifers compared to roosts used by solitary evening bats surrounding the maternity colony (Menzel et al. 2001*a*). Of the 33 maternity colonies found in the state by Hein (2008), 15 smaller colonies were in fork-topped trees and 18 larger colonies were found in tree cavities. Tricolored bats are known to utilize trees (Humphrey 1975) and squirrel nests (Veilleux et al. 2003) for maternity roosts. Veilleux et al. (2003) found that 19 reproductive tricolored bats in Indiana preferred oaks as roost trees, and roosted exclusively in foliage, with 65% in clusters of dead leaves, 30% in live foliage, and 5% in squirrel nests. In this study, they also found the mean roost tree height to be around 68 feet (20.8 m), the roost height from the ground to be 52 feet (15.7 m), and the roost tree diameter at breast height to be 13 inches (33.2 cm). Male tricolored bats in North Carolina are known to use large diameter oaks and hickories for roosts (Bunch et al. 2015*b*). In South Carolina, this species has been found in the cavities of bottomland hardwood tree species such as swamp chestnut oak (*Quercus michauxii*), sweetgum, and laurel oak (*Q. laurifolia*) (Carter et al. 1999), as well as in Spanish moss in understory trees on exposed high-marsh hammocks (Menzel et al. 1999*a*). Female tricolored bats often form maternity colonies of three to five individuals in clusters of live or dead leaves in trees, but basal cavities may also serve as maternity roosts (Menzel et al. 1996).

All *Myotis* species in South Carolina are colonial roosting bats, and include the eastern small-footed bat, little brown bat, northern long-eared bat, and southeastern bat. These species use roosts in tree cavities or under loose bark either during winter, summer, or both (Table 4). Eastern small-footed bats usually roost in human-made structures, caves, or mines, but are sometimes found beneath the bark of trees during summer (Barbour and Davis 1969). For little brown bats, maternity sites may be located in human-made structures, bat boxes, hollow trees, and taller, larger diameter trees in older forest habitat are commonly selected by tree-roosting reproductive females (Kalcounis and Hecker 1996, Crampton and Barclay 1998). Northern long-eared bats roost in tree cavities (Owen et al. 2001, Menzel et al. 2002*d*) and under the bark of trees (Mumford and Cope 1964). According to the USFWS (2015*b*), potential suitable summer habitat for northern long-eared bats may include live trees and/or snags with a dbh greater than or equal to 3 inches (7.62 cm) that have cavities, crevices, exfoliating bark, and/or cracks, and individual trees are within 1,000 feet (305 m) of forested habitat. In addition, wooded corridors and human-made structures should also be considered potential suitable summer habitat. Maternity colonies of this species have been found in trees, tree cavities, and under bark (Foster and Kurta 1999, Caceres and Barclay 2000, Whitaker and Mumford 2009). Many (though not all) studies show that female northern long-eared bats in maternity colonies prefer roosts in tall hardwood trees in early stages of decay (Sasse and Pekins 1996, Caceres 1998), in live trees with less canopy closure (Caceres 1998), and in large diameter trees (Sasse and Pekins 1996, Foster and Kurta 1999). In South Carolina during summer, a lactating northern long-eared bat was tracked to a location under the loose bark of a dead pine near National Forest land in Oconee County (Bunch and Dye 1999*b*).

Two bat species that most commonly utilize tree species associated with the bottomland hardwood forests of the Coastal Plain in South Carolina are the southeastern bat and Rafinesque's big-eared bat. Southeastern bats use various bottomland hardwood tree species such as large, live, hollow black gum and water tupelo with large basal openings (Cochran 1999, Hoffman 1999, Carver and Ashley 2008), sweetgum (*Liquidambar styraciflua*), Nuttall oak (*Q. nuttallii*), water hickory (*Carya aquatica*), water oak, red maple (*Acer rubrum*), American sycamore (*Platanus occidentalis*), American beech (*Fagus grandifolia*), bald cypress, Pignut hickory (*C. glabra*), swamp chestnut oak (*Q. michauxii*), and overcup oak (*Q. lyrata*) (Reed 2004, Wilf 2004, Stevenson 2008, BCI and SBDN 2013, Bat Conservation International 2015). During summer, this species prefers larger trees with larger cavities within 66 feet (20 m) of standing water (Mirowsky 1998), and the diameter at breast height of roost trees are often large, varying from 30 to 61 inches (76 to 155 cm) (BCI and SBDN 2013). In South Carolina, live tupelo gum trees within closed canopies were the primary roosting site for the southeastern bat in the Francis Beidler Forest (Clark et al. 1998). Despite being available, large bald cypress trees were not used as roost sites in the Francis Beidler Forest or in areas in Texas, even though they are used as roost sites in Mississippi (Clark et al. 1998, Mirowsky 1998, Stevenson 2008). Southeastern bats also roost in trees in winter, especially in southern regions. In Florida, they move from caves that are too warm to facilitate torpor to exposed roosts in tree hollows and human-made structures (Rice 1957, Humphrey 1992). Also, one study found this species may prefer larger trees with larger cavities during winter than spring and summer (Fleming et al. 2013). Rafinesque's big-eared bats are often found in roosts in hollow trees (Trousdale and Beckett 2005, Trousdale 2011), and sometimes found in tree crevices (Lance 1999) and beneath loose bark (Handley 1959). In South Carolina, they have been found in human-made roost towers in the Blue Ridge and Piedmont regions (Greenville and Pickens Counties), the Sandhills region (Aiken and Richland Counties), and in the Coastal Plain (Hampton County). Roost trees usually stand 59 to 82 feet (18 to 25 m) tall, have large cavities greater than 3.6 feet (102 cm) tall and 1.3 feet (39 cm) wide, and tend to be near water (Mirowsky 1998, Gooding and Langford 2004, Trousdale and Beckett 2005, Carver and Ashley 2008). However, Loeb and Zarnoch (2011) found that anthropogenic roosts used by the Coastal Plains and Sandhill populations (those of *C. r. macrotis*) were used significantly more than tree roosts during summer. Mountain populations (those of *C. r. rafinesquii*) in summer use roosts in cavity trees such as tulip poplars (*Liriodendron tulipifera*) (Bunch et al. 1998). Nursery colonies may form on vertical surfaces inside trees (Carver and Ashley 2008, Stevenson 2008). Also, roost tree density affects the social structure of Rafinesque's big-eared bats, where lower densities may lead to the use of only one focal maternity roost (Johnson et al. 2012). In South Carolina, maternity colonies have been found in tree cavities with approximately 100 individuals at Congaree National Park (National Park Service 2004). In the southern Coastal Plain where caves, mines, or other karst features are unavailable during winter, this species may remain in large hollow trees of closed canopy bottomland hardwood forests. Rafinesque's big-eared bats may choose larger diameter trees in winter than in spring and summer, as they've been known to do in the bottomland hardwood forests of Mississippi (Fleming et al. 2013).

Foliage roosting bats such as eastern red bats, hoary bats, northern yellow bats, Seminole bats, and silver-haired bats are highly dependent on trees for roosts throughout their life cycle. Stand and landscape features may be more influential for roost-site selection than tree and plot characteristics for these species as they often have high fidelity to specific sites despite switching tree roosts often within those sites (Lunney et al. 1988, Cryan et al. 2001, Elmore et al. 2004).

Eastern red bats are found roosting on leaf petioles and small branches in the tops of deciduous trees in summer (Barbour and Davis 1969). In central Illinois, Mager and Nelson (2001) found 89 % of roosts were in foliage or the trunks of deciduous trees greater than 18 inches (45 cm) dbh. Though eastern red bats are often found roosting in deciduous trees, Elmore et al. (2004) found that within thinned pine stands of Mississippi, 70% of their day roosts were found in 16 species of hardwood trees and 30% in loblolly pines. Also, preferred roosts were located within denser subcanopy and higher basal area, but specific tree characteristics were not as important as those at the stand-level. At the Savannah River Site, eastern red bat roosts were found in 23 total tree species, with sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*) used most (Menzel et al. 2000*a*). In the same study, roost trees were found in stands with larger basal areas, higher and denser overstory, and more diverse overstory and understory. In the Clemson Experimental Forest in South Carolina, female eastern red bats have been found to select trees on north and northwest facing slopes (Leput 2004), and roosts in Georgia and South Carolina forests were found at an average height of 50 feet (15.3 m) (Menzel et al. 1998). Though winter habits of eastern red bats are not well known in the state, they are found feeding throughout the year in southeastern Virginia and northeastern North Carolina at temperatures above 48°F (9°C) (Padgett and Rose 1991, Whitaker et al. 1997), and may hibernate in leaf clusters, tree branches, woodpecker cavities, old squirrel nests, leaf litter, and Spanish moss during colder winter temperatures (Constantine 1958, Barbour and Davis 1969, Fassler 1975, Saugey et al. 1989). Hoary bats have been known to roost in trees such as elm (*Ulmus* species), black cherry (*Prunus serotina*), plum (*Prunus* species), box elder (*Acer negundo*), and osage orange trees (*Maclura pomifera*) at about 10 to 16 feet (3 to 5 m) above the ground (Shump and Shump 1982*a*). Day roosts used by this species are almost exclusively in the foliage of trees (Shump and Shump 1982*a*, Willis and Brigham 2005). Hoary bats may also use tree cavities, Spanish moss, and old squirrel nests, especially during winter (Neill 1952, Cowan and Guiguet 1965, Constantine 1966). Northern yellow bats have been found roosting in Spanish moss in live oaks (*Quercus virginiana*) in Georgia and Florida (Jennings 1958, Menzel et al. 1995, Coleman et al. 2012), in pine-oak woodlands in Florida and Mexico (Sherman 1944, Jones 1964, Carter and Jones 1978), in the grooves of palm trees in Texas (Davis 1974), and on the stems of hardwoods in Virginia (Rageot 1955). Seminole bats commonly roost in oak hammock communities in Spanish moss from fall through spring and even during winter (Constantine 1958, Jennings 1958, Barbour and Davis 1969), but also in the canopy of live pine trees (Menzel et al. 1998, 1999*a*, 2000*a*, Perry and Thill 2007*a*) and sometimes roost under loose bark in the summer (Sealander 1979). Roost sites for this species often have west and southwest exposures that are thought to provide warmth from the sun (Constantine 1958, Wilkins 1987). Seminole bats may roost at heights great enough for the bat to drop into unobstructed space in order to take flight and vary from 3.6 to 14.8 feet (1.1 to 4.5 m), but may roost closer to the forest floor during colder weather (Constantine 1958). In South Carolina, this species may also roost in the terminal branches of pine limbs in pine dominated communities (Menzel et al. 1998), and at the Savannah

River Site roosts were primarily located in loblolly pines (*Pinus taeda*) (Menzel et al. 2000*a*). In the latter study, roosts tended to be in taller, larger trees found in areas with higher basal area, lower species richness understory, and less Spanish moss than neighboring trees. Silver-haired bats have shown a roosting preference for forests with large numbers of snags (Campbell et al. 1996, Mattson et al. 1996, Betts 1998) and old-growth forests (Thomas 1988, Jung et al. 1999). During summer, roosts and nursery sites for this species are often found in tree foliage, under loose bark, in narrow crevices in tree trunks, or in old woodpecker cavities (Parsons et al. 1986, Betts 1996, Mattson et al. 1996, Vonhof and Barclay 1996). In Washington, roosts included dead or dying trees with exfoliating bark, extensive vertical cracks, or cavities, and were significantly taller than surrounding trees with less overstory, less understory, and shorter understory vegetation than comparable random plots, and the height of summer roosts ranged between 20 to 50 feet (6.1 to 15.2 m) (Campbell et al. 1996). Maternity roosts for silver-haired bats are usually found in old woodpecker cavities (Parsons et al. 1986, Mattson et al. 1996, Vonhof and Barclay 1996) and in taller trees with retained tops protruding above the canopy (Betts 1998), possibly in order to better absorb sunlight and retain heat. Day roosts of males and non-reproductive females have been found in cavities as well as under loose bark on large trees in intermediate stages of decay (Mattson et al. 1996). During late summer and early fall, migrating silver-haired bats have been known to roost in narrow crevices in tree trunks at heights of 2.9 to 11.5 feet (0.87 to 3.5 m) with significantly larger circumferences than random samples (Barclay et al. 1988). In Arkansas, Perry et al. (2010) found that 90% of winter roosts were in five species of trees, and most were on southern topographic aspects. Of all roosts, 55% were under loose bark and 6% were either under a tree roost or in a cavity at the base of a live pine. Pine or pine-hardwood stands greater than 50 years old and used forest stands between 15 and 50 years old were selected as winter roosts by silver-haired bats in this study.

Artificial bat roosts

Typical bat boxes, multi-chamber nursery boxes, and structures that mimic large hollow trees such as large bat towers are all examples of artificial bat roosts used by colonial roosting bats in South Carolina. Almost any bat that roosts in buildings or under bridges is a candidate for the use of various bat boxes. However, certain species may require specific types of bat boxes. For example, typical bat boxes are best used for big brown bats (and potentially Brazilian free-tailed bats, evening bats, silver-haired bats, and tricolored bats) (Tuttle et al. 2005). Multi-chamber nursery boxes are best used for eastern small-footed bat, little brown bat, and northern long-eared bat colonies, and bat towers are best used for Rafinesque's big-eared bats and southeastern bats.

For an artificial roost to be successfully used by bats, it is important to determine the correct placement, design, and construction for target bat species (Kiser and Kiser 2004). For example, artificial roosts should have a south, east, or west facing aspect for better heat absorption (Mering and Chambers 2014). Additionally, understanding local, natural bat populations before providing artificial roosts will help prevent unintentional negative impacts on the species composition of those populations. For example, providing artificial roosts was shown to increase the population of a dominant bat and caused a forest bat that did not use artificial roosts to become increasingly rare (Bender 2005). A way to prevent this may be to create alternative roosts that closely mimic the natural roosts of target species in design, height, and microclimate (Mering and Chambers 2014). Alternative roost sites are useful for bats evicted from buildings or other human-made structures; yet they should not generally be considered an effective mitigation measure for replacing natural roost sites. However, they can be used in forests as supplemental bat roosts (Mering and Chambers 2012). There are many online resources for the purchase of bat boxes as well as how to construct them, such as BCI's "The Bat House Builder's Handbook" (Tuttle et al. 2005).

Bat boxes have been set up at South Carolina state parks such as Oconee State Park and Table Rock State Park, which have seen use by little brown and big brown bats. Also, when bat boxes have been provided during exclusion from nearby structures, big brown bats and Brazilian free-tailed bats have been known to move to those bat boxes. However, there is still room for improvement in bat box design in the southeast because extreme heat can cause bats to hang out of the bottom of the box and potentially drop pups on the ground. In terms of bat towers in South Carolina, one or more Rafinesque's big-eared bats have made use of five out of seven set up across the state thus far, located in the Blue Ridge and Piedmont regions (Greenville and Pickens Counties), the Sandhills region (Aiken and Richland Counties), and in the Coastal Plain (Hampton County).

Foraging and Commuting Habitat

Of the 18 bat species that occur in the southeast, all rely on forests for foraging habitat (Hall 1981). Habitats used during foraging bouts by bats in South Carolina are extremely variable, covering most habitat types available except offshore marine waters. These habitats range from wetlands and riparian areas, bottomland hardwoods such as bald cypress-tupelo gum swamps and beech-magnolia bottoms, coastal prairies, hammocks, Carolina bays, loblolly-slash pine habitats, pine savannahs, pine barrens, oak habitats, open grasslands, agricultural lands and floodplains, mixed and mature deciduous uplands, edges of clearcuts, golf courses, airports, and rural and urban areas. Within these habitats, bats may feed over streams, ponds and lakes, along cliff faces, in the forest canopy or understory, in unfragmented forest, or in forest openings. Most foraging activity generally occurs along edge habitats or in open sites such as golf courses, fields, clearcuts, and forest gaps, potentially because these areas are where the highest concentrations of insects are most easily consumed compared to areas of vegetational clutter found in interior forest habitat. However, species such as Rafinesque's big-eared bats are known to avoid large open areas (Clark 1990, 1991), and according to Menzel et al. (2001), big brown bats in the southeast may prefer hardwood and pine forests over agricultural fields and clear cuts. As mentioned in the Foraging Behavior section of this document, wing loading, wing aspect, and echolocation characteristics of bats play a significant role in what habitats they are best able to exploit. For example, the high wing loading and aspect ratio of Brazilian free-tailed bats and hoary bats indicate fast, long-distance migrators that catch insects on the wing in open areas. Foraging habitats may also vary over an evening for some species. For example, little brown bats initially feed along margins of lakes and streams and in and out of vegetation 7 to 16 feet (2 to 5 m) above the ground, and later forage 3 to 7 feet (1 to 2 m) over the surface of water in groups (Fenton and Bell 1979).

Water

Many species of bats in South Carolina incorporate water in their foraging areas, whether it is over, adjacent to, or along margins of bodies of water, wetlands, riparian areas, or bottomland hardwood swamps. Riparian areas are well known to be extremely important foraging habitats for bats. For example, the majority of the activity of tricolored bats tends to occur in riparian areas, as seen in studies in Georgia (Ellis et al. 2002), South Carolina (Menzel et al. 2005*b*), and an Appalachian forest in West Virginia (Ford et al. 2005). Many species benefit from riparian areas, as bat activity of five species in South Carolina were found to be highest in riparian areas but was relatively low in upland habitats at heights around 7 and 33 feet (2 and 10 m) in intensively managed pine-dominated landscapes of the Coastal Plain (Menzel et al. 2005*b*).

Local habitat types

Bottomlands, pine forests, and upland forests are major habitat types in South Carolina used as foraging areas by bats. At the Savannah River Site, Carter et al. (2004) found that evening bats were most active in pine forests (59%) and bottomlands (37%), but rarely foraged in upland hardwoods, whereas the habitat types selected by Seminole bats included 55% pine forests, 35% bottomland hardwoods, and 11% upland hardwoods. For eastern red bats at the same site, Carter (1998) found the habitat types within their home range were 55% bottomland hardwoods, 40% pine stands, and 5% upland hardwoods. Bottomland hardwoods and pine stands were also reported as foraging areas for tricolored bats (Carter et al. 1999), and Menzel et al. (2003*b*) reported the greatest activity around lakes and ponds, bottomland hardwood forests, and grass-brush habitats. Also at the Savannah River Site, evening bats were found using gaps in bottomland hardwood and swamp forests (Menzel et al. 2001*a*). Rafinesque's big-eared bats in the mountains that had been captured and fitted with radio transmitters in the Eastatoe Valley foraged in and around forested bottomlands and a cornfield in Eastatoe Valley (Mary Bunch, SCDNR, pers. comm.). At the Silver Bluff Plantation in the Upper Coastal Plain, reproductive male Rafinesque's big-eared bats fed in uplands in young pine stands where sapling stage stands were preferred over sawtimber stands, despite the fact that mature bottomland hardwoods were common in the study area (Menzel et al. 2001*c*). Additionally in this region, southeastern bats are known to forage most actively in Carolina bay wetlands, bottomland hardwood forests, river swamps, and forest gaps (M. A. Menzel et al. 2003, Menzel et al. 2005*b*, Ford et al. 2006*a*). This species also prefers to forage over water in bald cypress-tupelo gum swamps and bottomland hardwood forests in Illinois, Arkansas, and South Carolina (Clark et al. 1998, Hoffman et al. 1998, Hoffman 1999). Pine and oak habitats are important to northern yellow bats as Krishon et al. (1997) found that the home range of a single bat was located in oak habitat the majority of the time but was also found in loblolly and slash pine communities.

Rural and urban areas play a role as foraging habitat, particularly because lights found in these areas are known to attract insects. Big brown bats forage around lights in rural areas (Geggie and Fenton 1985), and according to Menzel et al. (2001) may prefer rural rather than urban areas. Eastern red bats also feed around lights, and may land on light poles to catch moths (Barbour and Davis 1969, Hickey and Fenton 1990)

Foliage height

Bats may forage above or below tree foliage, depending in large part on their ability to navigate cluttered areas within or under the forest canopy. Brazilian free-tailed bats hunt in open spaces well above the trees of woodlands and forests, and hoary bats forage in open areas within the forest, above the forest canopy, and over lakes and streams (Shump and Shump 1982*a*, Barclay 1985, Nagorsen and Brigham 1993). Big brown bats may prefer foraging among tree foliage rather than above or below the forest canopy (Schmidly 1991), though they were more often detected above the forest canopy in a South Carolina study by Menzel et al. (2005). Tricolored bats are sometimes known to feed over the top of streamside vegetation and taller streamside trees (Caire et al. 1984, Harvey et al. 1999*a*), but along with eastern red and Seminole bats, their activity did not differ above, within, or below the forest canopy in the study by Menzel et al. (2005). Eastern small-footed bats usually forage in forest understory and canopy (Merritt 1987, Linzey 1998, Harvey et al. 1999*a*), however, migrating females foraged along streams below the canopy in New Mexico (Valdez and Cryan 2009). When studying the activity of bats at different sampling heights in five habitat types of the Coastal Plain in South Carolina, Menzel et al. (2005) found that at between 7 and 33 feet (2 and 10 m), activity was more concentrated in riparian areas compared to heights of about 98 feet (30 m) where activity was more evenly distributed across habitat types. Additionally, the levels of bat activity above the forest canopy were much greater than within or below the canopy.

Forest stand age

Foraging activity of bats is often related to forest stand age. At the Savannah River Site, Menzel et al. (2003*b*) found the most evening bat activity was highest in clearcuts and young stands, moderate in stands greater than 60 years old, and lowest in stands between 21 to 60 years old. For tricolored bats, the most activity was also in clearcuts (as well as roads and open water habitats) with moderate activity in stands four to 20 years old. However, foraging activity of big brown bats in the same study appeared to be unaffected by stand age. In the Coastal Plain of South Carolina, southeastern bats are known to forage in stands of trees between 21 to 40 years (M. A. Menzel et al. 2003, Menzel et al. 2005*b*, Ford et al. 2006*a*). Mature forests, mature deciduous uplands, and mature forested wetlands are also important roosting and foraging habitats for bats, especially northern long-eared bats (Kunz 1971, 1973, Caceres and Pybus 1997) and southeastern bats (Gardner et al. 1992, Horner 1995, Gardner 2008). Also, old growth swamp forests in South Carolina represented the majority of the area used by radio-tagged Rafinesque's big-eared bats at Francis Beidler Forest (Clark et al. 1998).

Intensively managed areas

For habitat that has been thinned or burned, bats may respond differently according to their environmental niche and habitat preferences. In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of big brown bats and eastern red bats to be significantly higher in thinned tree stands compared to control or burned stands. However, tricolored bats did not vary significantly between thinned, burned, or the control tree stands.

Forested corridors on intensively managed pine landscapes are important foraging areas for bats. For example, Hein (2008) studied six bat species in the Lower Coastal Plain and found an overall positive response to forested corridors on intensively managed pine landscapes. Compared to interior corridors or adjacent stands, there were higher occupancy rates by bats along edge habitat. Also, bat activity was negatively related to adjacent stand age and positively related to the overstory height of the corridor. At the Savannah River Site, Menzel et al. (2002*b*) studied the feeding and foraging activity of bats below the forest canopy on different timber harvest stands at three different special scales. The researchers found that on the landscape scale, more activity occurred in bottomland stands with harvested patches and around Carolina bays compared to unharvested bottomland and upland hardwoods and pines. For harvested and unharvested areas in stands where patches were harvested, activity was highest along skidder trails and forest gaps. Within individual gaps, the highest activity occurred along the forest edge. Additionally, these patterns of activity depended on the bat species.

Chapter 3: Species Accounts

In this chapter are individual accounts of the 14 species commonly found in South Carolina. They are arranged in alphabetical order by common name and provide information on identification, taxonomy, distribution, population status, habitat, behavior, reproduction, food habits, seasonal movements, longevity, survival, threats, and conservation measures. The current known distribution of each species is shown in the range maps and indicated by shaded South Carolina counties. Additionally, a summer and winter range are provided for the migratory silver-haired bat, a suspected range for the little brown bat is shown with crosshatching, and an asterisk indicates incidental records for the southeastern bat. This range map information is based on museum records, capture records maintained by the SCDNR, records from rabies testing maintained by the state's epidemiology lab, and captures recorded in published and unpublished literature such as reports and scientific literature (Menzel et al. 2003*a*, Mary Bunch, SCDNR, pers. comm.). Size measurements based off of Menzel et al. (2003*b*) are shown in Table 5. Incidental records exist of the big free-tailed bat (*Nyctinomops macrotis*) and the federally endangered Indiana bat (*Myotis sodalis*) (DiSalvo et al. 1992, NatureServe 2017). However, these species are not addressed in this document due to their rarity in the state.

Table 5: Size measurements of bat species in the southeastern US. Modified from Menzel et al. (2003*b*).

Species	Weight (g)	Total Length (mm)	Forearm Length (mm)	Wing Length (mm)	Hind foot Length (mm)	Ear Length (mm)	Tragus Length (mm)	Wing-aspect Ratio Index [a]	Wing Loading Index [b]
Big Brown Bat	15.3	111.6	45.9	138.3	9.6	16.9	6.1	2.47	1.97
Brazilian Free-tailed Bat	11.5	93.1	43.4	133.0	9.2	16.9	1.7	3.05	2.02
Eastern Red Bat	10.0	101.8	39.5	138.0	7.9	11.3	4.3	2.64	1.39
Eastern Small-footed Bat	4.2		31.0		6.0	14.0	5.0		
Evening Bat	8.0	86.8	36.2	114.0	7.9	11.9	3.9	2.43	1.49
Hoary Bat	21.2	132.5	55.2	183.0	11.5	14.9	7.3	2.94	1.88
Little Brown Bat	6.5	87.4	37.0	107.7	8.1	13.5	5.7	2.23	1.26
Northern Long-eared Bat	8.0		35.1		7.2	15.3	6.8		
Northern Yellow Bat	20.0	127.6	51.7	158.3	10.4	17.7	7.7	2.58	2.06
Rafinesque's Big-eared Bat	8.6	96.1	43.4	127.0	11.8	32.2	12.7	2.27	1.21
Seminole Bat	10.1	103.9	41.5	138.3	8.4	12.1	6.3	2.66	1.59
Silver-haired Bat	9.3	99.5	41.6	128.3	8.0	14.8	4.6	2.57	1.45
Southeastern Bat	5.7	86.6	37.1	115.0	9.6	13.9	6.7	2.3	0.99
Tricolored Bat	5.4	83.6	34.3	97.7	8.1	12.7	4.7	2.27	1.28

[a] Wing length/length of fifth phalanx; higher numbers indicate longer, narrower wings.

[b] [Mass/(wing length x length of fifth phalanx)] x 1,000; higher numbers indicate higher body mass per unit of wing area.

Big Brown Bat (*Eptesicus fuscus*)

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Description

One of the most widespread and abundant bat species in North America, the big brown bat is ubiquitous in South Carolina. This species is the third largest bat in the state, and like most bats is extremely beneficial ecologically. According to Whitaker (1995), in one summer a colony of 150 big brown bats consumes enough adult spotted cucumber beetles to prevent the production of 33 million of their larvae, a major pest of corn. This species is closely associated with humans, often roosting in human-made structures and commonly using buildings as hibernacula. Because of this, wildlife control operators are frequently hired to exclude them from homes. Big brown bats are also known for their homing ability, though the release direction from their roost played a large factor in the return rate.

Identification

The big brown bat is a medium sized bat, with males slightly smaller than females (Burnett 1983). This species weighs 0.5 to 0.7 ounces (14 to 21 gr) and has a wingspan of 13 to 15 inches (32 to 39 cm) (Harvey et al. 2011). Big brown bats have a relatively heavy body, black ears and wing membranes, and a large head with a broad nose and powerful jaw. The pelage is dark above and light below and varies from glossy dark brown to pale. The ears and tragus are short and rounded.

Taxonomy

Currently there are 12 recognized subspecies (Wilson and Reeder 2005) of the big brown bat, and only *Eptesicus fuscus fuscus* has been confirmed in South Carolina (Kurta and Baker 1990).

Distribution

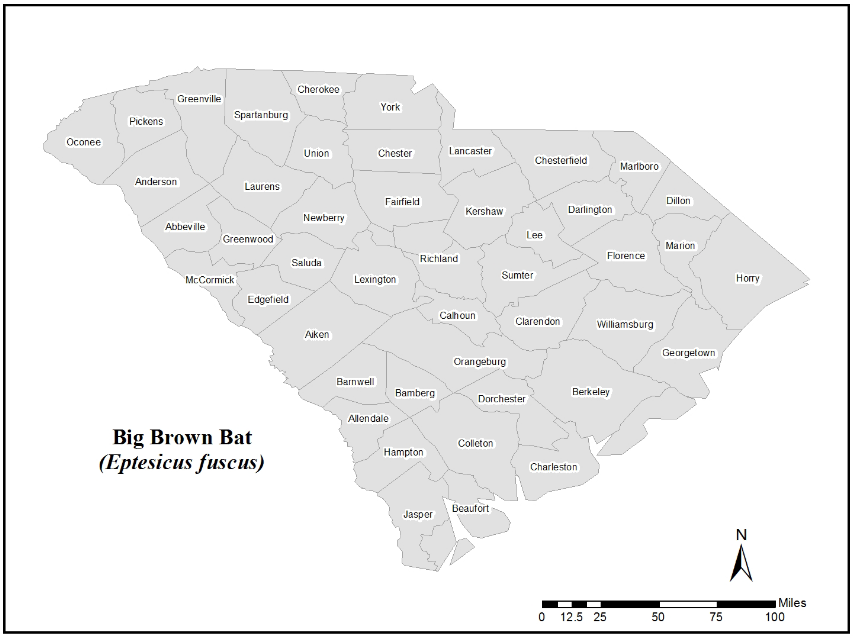
Big brown bats range from southern Canada through southern North America into South America, and are present on islands of the Caribbean (Harvey et al. 2011). In South Carolina, they are distributed statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003).

Population Status

Considered the most common bat species through most of its range, the big brown bat is ranked as Globally Secure (G5), Nationally Secure (N5) and Subnationally Secure (S5) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Miller et al. 2008). However, this species is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015) due to severe WNS-related mortality occurring in the northeast.

General Habitat

The big brown bat is a habitat generalist found in a wide variety of habitats, ranging from lowland deserts to timberline meadows (Furlonger et al. 1987). The abundance of this species increases as one moves from the Coniferous Forest Biome to the Deciduous Forest Biome of eastern North America (Kurta et al. 1989*b*), and is also abundant in urban areas. In mountainous regions of south-



central British Columbia, males are known to occur at higher elevations than females (Fenton et al. 1980). In South Carolina, sparse vegetation was found to be the best predictor of habitat use by big brown bats (Loeb and O'Keefe 2006).

Roosts and Roosting Behavior

During summer, big brown bat summer roosts can be found in hollow oak (*Quercus*) and American beech (*Fagus grandifolia*) (Christian 1956, Kurta 1980). Maternity colonies were traditionally found beneath loose bark and in small cavities of pine, oak, beech, bald cypress and other trees (Bat Conservation International 2015), but now often roost in human-made structures such as houses, barns, churches, attics, bridges, behind chimneys, in hollow walls and in enclosed eaves (Barbour and Davis 1969, Kurta and Baker 1990). In South Carolina, two individuals in a bottomland hardwood swamp were tracked to a maternity colony in a hollow bald cypress (Carter 1998, Menzel 1998). Maternity colony size in the eastern US ranges from 25 to 75 adults, but can vary from five to 700 individuals elsewhere (Davis et al. 1968, Kurta 1980, Mills et al. 1975). Colony size may depend partially on roost size as larger cavities of roost trees have been found to be correlated with larger numbers of reproductive female big brown bats (Willis et al. 2006). About 72% of adult females have strong maternity roost site or area fidelity and return to the natal roost in successive years, but only 10 to 30% of immature females do the same (Davis 1967, Brenner 1968, Mills et al. 1975).

Males may roost with females or in all-male colonies, but are most often solitary during summer (Davis et al. 1968, Barbour and Davis 1969). Generally, summer roost sites are located in buildings, hollow trees, rock crevices, tunnels, and even cliff swallow nests (Christian 1956, Barbour and Davis 1969, Kurta 1980, Kurta and Baker 1990). Males may join nursery groups to form large late-summer colonies when young are able to fly (Barbour and Davis 1969). Torpor is regularly used during summer while day roosting by females. Males also use torpor, but they enter it more deeply and use it more often than reproductive females (Hamilton and Barclay 1994, Lausen and Barclay 2003). Night roosts may include garages, breezeways, and house porches (Harvey et al. 2011). By August, summer colonies begin to disperse (Barbour and Davis 1969).

During winter when the weather is extremely cold, this species can be found hibernating in caves, mines, rock crevices, storm sewers, and in attics, basements, and wall spaces of buildings (Goehring 1954, Barbour and Davis 1969, Vonhof 1995, M. A. Menzel et al. 2003).

In fact, buildings are considered the most important hibernacula for big brown bats in northwestern US, who may lose 25% of their pre-hibernation body weight by the end of the hibernation period (Nagorsen and Brigham 1993, Maser 1998). They are known to enter and leave their hibernacula throughout the winter (Mumford 1958). Winter colonies rarely include more than a few hundred individuals, but usually they are solitary or found in small groups. Both sexes have been known to hibernate together (Whitaker and Gummer 2000). However, not much is known about the roost habits of big brown bats during winter in South Carolina.

Reproduction

Mating occurs between September and March (Mumford 1958, Phillips 1966), and sperm is stored in the female's uterus until spring when fertilization takes place. Twins are usually born from May through July (usually early June) in the eastern US (Christian 1956, Barbour and Davis 1969). Gestation lasts 60 days, lactation lasts 32 to 40 days and young begin to fly at four to five weeks (Kunz 1974, Kurta and Baker 1990). Only some females of this species reproduce at the end of their first year (Schowalter and Gunson 1979), but males reach sexual maturity by autumn of the first year (Christian 1956). The reproductive habits of this species are unknown in South Carolina.

Food Habits and Foraging

Emerging within the first hour after sunset, the flight of big brown bats to foraging areas is at a height of approximately 20 to 35 feet (6 to 10 m) and is strong and direct (Harvey et al. 2011). The flight speed of this species out in the open is 20.5 miles per hour (33 kmph), or 8 to 11 miles per hour (13 to 18 kmph) in an enclosed area (Craft et al. 1958, Patterson and Hardin 1969). Big brown bats travel an average distance of about 0.62 to 1.24 miles (1 to 2 km) to foraging areas from their day roost (Brigham 1991). This species flies for an average of one hour and 40 minutes each night, with the majority of foraging activity happening within the second hour after sunset (Kurta and Baker 1990). Each night a few foraging bouts are made, interspersed with night roosting. Some individuals may even follow the same feeding pattern on different nights, and use the same feeding ground each night (Harvey et al. 2011).

Big brown bats are known to forage in a wide variety of habitats including open areas such as fields or large gaps within forests, over water and lake edges, and foraging around lights in rural areas (Geggie and Fenton 1985, Kurta and Baker 1990, Menzel et al. 2001*b*). Females are known to use an average foraging area of 1 mi^2 (2.7 km^2) compared to 2 mi^2 (5 km^2) for males (Wilkinson and Barclay 1997). When comparing activity in National Parks, big brown bat activity was found to be lowest in fragmented rural parks and greatest in urban forest parks (J. B. Johnson et al. 2008). Additionally, within urban habitats foraging activity was found to be lowest in commercial areas and greatest in parkland and residential areas (Geggie and Fenton 1985). This species may prefer foraging among tree foliage rather than above or below the forest canopy (Schmidly 1991), but in South Carolina has been known to forage above the forest canopy (Menzel et al. 2005*b*). In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of big brown bats to be significantly higher in thinned tree stands compared to control or burned stands. According to Menzel et al. (2001), big brown bats may also prefer rural rather than urban areas, and hardwood and pine forests over agricultural fields and clear cuts in the southeast. In the same study, the average home range size was large at 7,180 acres (2906 ha). At the Savannah River Site, foraging activity appeared to be unaffected by stand age and was concentrated over lakes and ponds, grass-brush, and bottomland hardwoods (M. A. Menzel et al. 2003). In South Carolina, the activity of big brown bats has been recorded widely around Lake Jocassee and Lake Keowee, in April, July and October at 29 of the 31 sites surveyed (Webster 2013). However, the specific foraging habits of big brown bats in the state are not known.

The powerful jaw and heavy teeth of this species assists in consuming beetles, which constitutes most of their diet (Phillips 1966, Whitaker 1972, 1995, Menzel et al. 2000*b*). However, in some areas Lepidoptera are an important dietary source for big brown bats, and they also feed on Isoptera, Hemiptera, Homoptera, Hymenoptera, Diptera, Ephemeroptera, and Plecoptera (Ross 1967, Freeman 1981, Menzel et al. 2000*b*, Harvey et al. 2011). Four percent of stomach contents are made up of nonflying prey and vegetation in Indiana (Whitaker 1972). In Georgia, this species fed mostly on Coleoptera and Lepidoptera (Carter et al. 1998). Also in Georgia, females during the reproductive period may choose to forage on coleopterans over lepidopterans, dipterans, and hymenopterans based on the availability of these insects in the foraging area (Menzel et al. 2000*b*). In South Carolina, Coleoptera and Lepidoptera have been known to make up the majority of this species diet, though evidence of other insects were also found (Donahue 1998).

Seasonal Movements

This species is considered sedentary and their movement from summer roosts to hibernacula is less than 56 miles (90 km) (Mills et al. 1975, Neubaum et al. 2006). Big brown bats have been shown to move extensively due to their homing ability, as Reite and Davis (1966) reported that 85% returned when released about 250 miles (400 km) north of their roost, while only 6% returned when released from the south the same distance.

Longevity and Survival

Though few individuals actually live to a relatively old age, big brown bats are capable of living at least 20 years in the wild (Davis 1986). Survival rates are higher in adults than in juveniles (O'Shea et al. 2010, 2011). Based on banding data, the estimated mean annual survival for males is 0.70 years and for females is 0.47 years (Hitchcock et al. 1984). Hitchcock also calculated an average annual survival rate for big brown bats in Minnesota of 82% for males and 74% for females.

Threats

Mortality from WNS may be a potential threat for big brown bats. However, a recent study shows that this species is highly resistant to WNS. In big brown bats, the degree of infection by *Pd* may be limited to the outer epidermis during torpor, preventing lesions, evaporative water loss, and subsequent short torpor bouts thought to prematurely burn fat reserves during hibernation (Frank et al. 2014).

Disturbance or destruction of natural and artificial roost structures may be a potential threat to this species, and many forms of habitat alterations can also cause increased predation by natural predators (Bunch et al. 2015*b*).

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock (Bunch et al. 2015*b*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Wind energy may threaten big brown bats as well, as fatalities of this species at wind turbines have been documented (Gruver 2002, Arnett et al. 2008). Big brown bats have been one of six bat species killed at a wind power developments at Buffalo Ridge, Minnesota and Buffalo Mountain Windfarm, Tennessee (Johnson et al. 2003, Fiedler 2004). However, the percentages of fatalities are still relatively low compared to migratory tree bats. For example, big brown bats comprised 1.9% of the total fatalities in a review of bat mortality at wind energy developments in the US by Johnson (2005), and were 3% of the total bat fatalities found by Arnett et al. (2009) at the Casselman Wind Project in south-central Pennsylvania. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Small numbers of deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981). However, the level of impact from tower mortalities on local or range wide populations remains unclear.

Global climate change is a potential threat to big brown bats because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to big brown bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and typical bat boxes are a reasonable alternative for big brown bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the big brown bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Brazilian Free-tailed Bat (*Tadarida brasiliensis*)

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Description

Brazilian free-tailed bats differ from all South Carolina bats in that they are a member of the Molossidae or "free-tailed bat" family and have a characteristic mouse-like tail extending past the membrane stretched between the hind legs. This species forms the largest concentrations of mammals in the world. Each year 100 million bats arrive in central Texas to raise their young, and the largest known bat colony in the world holds 20 million of those at Bracken Cave near San Antonio during the summer (Harvey et al. 2011). The impressive number of insects consumed by these colonies provides a substantial pest control service to humans. In an eight county region in south-central Texas, the value of pest control provided by Brazilian free-tailed bats was estimated at $741,000 per year for cotton producers (Cleveland et al. 2006). The Mexican free-tailed bat, a subspecies of the Brazilian free-tailed bat, provides a total annual cotton pest-suppression service of $11.67 million in the southwestern US and northern Mexico (López-Hoffman et al. 2014). Unfortunately, wind energy development may pose a threat to this species. Piorkowski and O'Connell (2010) showed a steady rate of collision mortality and from the seven bat species killed by wind turbines, 85% of all fatalities were Brazilian free-tailed bats.

Identification

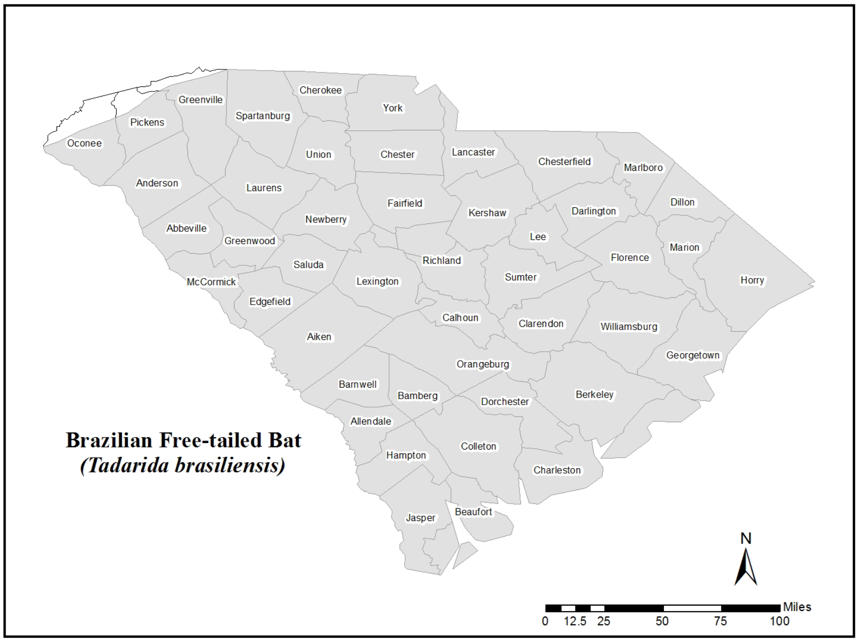
The Brazilian free-tailed bat is a small to medium sized bat weighing 0.4 to 0.5 ounces (11 to 15 gr) and has a wingspan of 11 to 14 inches (29 to 35 cm) (Harvey et al. 2011). The upper lip is strongly wrinkled, the blackish ears are short and nearly square, and the short, velvety pelage is dark brown to dark gray. However, the pelage may bleach to various shades of reddish brown depending on the concentration of ammonia found at their roost site (Tuttle 1994). The wings are long and narrow and the membranes are blackish. Short, powerful hind legs and large feet give this species excellent climbing abilities, and long hairs protruding from the toes are thought to judge flight speed and turbulence. Brazilian free-tailed bats are the fastest of all North American bats, flying at speeds of up to 40 to 60 miles per hour (65 to 95 kmph) (Whitaker and Hamilton 1998).

Taxonomy

Currently there are nine recognized subspecies of the Brazilian free-tailed bat (Wilson and Reeder 2005). *Tadarida brasiliensis cynocephala*, also referred to as Le Conte's free-tailed bat, is the only subspecies found in South Carolina (M. A. Menzel et al. 2003).

Distribution

This species is one of the most widely distributed mammals in the Western Hemisphere (Wilkins 1989). It is found southward from the southern US through Mexico and Central America, and into large areas of South America. It is also present on islands of the Caribbean (Harvey et al. 2011).



In the past, Brazilian free-tailed bats were mainly distributed throughout the state south of the Piedmont region, but in recent years they have been commonly recorded in the upper Piedmont.

Population Status

Common through most of its range, the Brazilian free-tailed bat is ranked as Globally Secure (G5), Nationally Secure (N5) and Subnationally unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Apparently Secure (S4S5) by the SCDNR Heritage Trust (see Table 2). It is currently classified as Least Concern (LC) on the IUCN Red List (Barquez et al. 2008). This species is also considered locally common, and not a Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

General Habitat

From pine-oak forests from sea level to 9,000 feet (2,743 m) in elevation, to pinion-juniper woodlands and desert ecosystems, this species is found in a wide variety of habitats throughout its range (Bat Conservation International 2015). They are also found in grassland, savanna, shrubland, suburban and urban habitats (NatureServe 2017).

Roosts and Roosting Behavior

Summer and winter roosting habits for this species tend to be very similar. In the southeast, natural roosts for this species used to be hollows of mangroves and cypress trees (Jennings 1958). Today they are found mainly in human-made structures, day roosting in tight colonies in undisturbed buildings and attics at least 9.8 feet (3 m) above the ground in order to attain flight through free fall when departing from the roost (Jennings 1958, Barbour and Davis 1969). They may also be found under bridges, in tunnels and hollow trees (Lowery 1974, Tuttle 1994). Brazilian free-tailed bats are thought to feed all night and therefore rarely use night roosts (Whitaker and Hamilton 1998). However, specific roosting habits for this species in South Carolina are unknown.

During spring and summer, sexes generally roost in separate locations. Males form groups from dozens up to 100,000 individuals at elevations over 9,000 feet (2,740 m), while females usually form maternity colonies below 5,000 feet (1520 m) in warm, dry areas of the species' northern range (Freeman and Wunder 1988, Tuttle 1994). The number of adult females in maternity colonies ranges from a minimum of 20,000 to 20 million found in Bracken Cave near San Antonio, Texas (Caire et al. 1989, NatureServe 2015). However, southeastern colonies are usually composed of less than 50,000 individuals (M. A. Menzel et al. 2003), and colonies of Le Conte's bat (*T. b. cynocephala*) don't generally exceed several thousand individuals in Florida (Bain 1981). Females do not roost with their offspring, but instead deposit them in a crèche and visit them several times a day to nurse. Large maternity colonies roost in limestone caves, abandoned mines, buildings, and bridges, while smaller colonies roost in hollow trees (Wilkins 1989, Bat Conservation International 2015). Females tend to return to natal caves to breed (Caire et al. 1989). Sites with relatively hot temperatures are often chosen, and large numbers of individuals generate enormous amounts of heat essential for the rapid growth of young bats (Kunz and Robson 1995). The guano from these large colonies, along with fallen bats, is consumed by dermestids on the cave floor. The waste from these carpet beetles, when combined with water vapor, can create enormous concentrations of ammonia lethal to humans. Brazilian free-tailed bats survive this by lowering their metabolic rate and accumulating carbon dioxide in their blood and respiratory mucus, which neutralizes the ammonia (Tuttle 1994). The copious amounts of guano associated with this species tend to accumulate in commercially significant amounts and have been mined for fertilizer and gunpowder manufacturing (Hutchinson 1950).

During winter in the western US, this species is not a true hibernator and migrates south for the winter, but in the southeast is apparently nonmigratory and may enter torpor for short periods during extremely cold weather (Barbour and Davis 1969, Lowery 1974, Wilkins 1989). Little is known about the roosting habits of Brazilian free-tailed bats in South Carolina during winter, though they likely overwinter in buildings. In order to keep warm, the clustering behavior of *T. b. cynocephala* increases bat cluster compactness as the temperature decreases (Pagels 1975). Roosting groups are probably much smaller during winter than those during summer. For example, in Florida about 10,000 bats summered in a house in Gainesville but by winter only a few hundred remained (Whitaker and Hamilton 1998).

Reproduction

Unlike many bat species, female Brazilian free-tailed bats do not store sperm for a considerable amount of time over winter. Mating occurs in mid-Feb to late March (Wilkins 1989), and shortly thereafter the females migrate to maternity roosts. Gestation lasts from 77 to 100 days (Feldhamer et al. 2003), and typically one pup is born from late May to late June (or as late as early August) (Sherman 1937, Barbour and Davis 1969, Wilkins 1989). The fat content of the milk fed to the pups is one of the highest reported for bats at over 28% (Sosnicki 2012), and thus their growth is relatively quick. Lactation lasts about 45 days, and young begin to fly and forage at five to six weeks (Kunz and Robson 1995). Amazingly, a female can find her young in a colony of thousands of pups by recognizing the calls and scent of her own pup (McCracken and Gustin 2010). Females of this species become sexually mature around nine months, while males are not sexually mature until their second year (Sherman 1937).

Food Habits and Foraging

Emerging around sunset (Bailey 1951), Brazilian free-tailed bats can cover an area of 154 miles squared (400 km^2) and are thought to feed all night (Lee and McCracken 2005). The numbers of this species are often so great that they can be detected by airport and weather radar, and the sound of their wings have been compared to that of a roaring river as they fly out from their roosting colonies. The Brazilian free-tailed bat has the highest recorded flight altitude among bats at over 10,826 feet (3,300 m) and may fly up to 150 miles (241 km) to reach foraging areas (Williams et al. 1973). They typically travel at a height of approximately 50 feet (15 m) to reach foraging areas, and feed within 50 miles (80 km) from the day roost (Whitaker et al. 1980). This species is highly adapted to an aerial lifestyle involving fast, direct flight, and can fly up to 40 to 60 miles per hour (65 to 95 kmph) (Whitaker and Hamilton 1998). With a high wing aspect ratio and wing loading, they are only moderately maneuverable (Vaughan 1966) and hunt in open spaces, usually well above the trees of woodlands and forests. About 60% of its time is spent foraging while cruising, 12% spent foraging, and the rest spent cruising and resting (Caire et al. 1984).

As an opportunistic insectivore, the diet of this species varies based on geographical range but includes Lepidoptera, Coleoptera, Diptera, Hymenoptera, Homoptera, Heteroptera, Neuroptera, and Trichoptera (Whitaker 1995, Whitaker and Hamilton 1998, Schwartz and Schwartz 2001). For example, Ross (1961) and Storer (1926) found 90% of their diet consists of moths from the Gelechiidae family between 5 and 9 mm long. During feeding bouts, a population of this species in Texas was found to eat coleopterans and lygaeid bugs in the evening and moths in the morning (Whitaker et al. 1996). It is estimated that the 100 million Brazilian free-tailed bats in central Texas caves significantly impact local populations of insects and agricultural pests, such as cotton bollworm moths and army cutworm moths, by consuming 1,000 tons of insects nightly (McCracken and Westbrook 2002). Not much is known about the diet of Brazilian free-tailed bats in South Carolina, however.

Seasonal Movements

Some subspecies of the Brazilian free-tailed bat in the Great Plains, Texas, and the southwest are known to migrate great distances to Mexico, though some males in the Great Plains have been known to remain in their winter range during the summer instead of migrating north in the spring (Glass 1982). However, in South Carolina this species is resident all year and flying individuals have been shot in the state in January (Whitaker and Hamilton 1998).

Longevity and Survival

The longest-lived individual of this species in the wild has been recorded at eight years, while that of a captive individual was recorded at 12 years (Weigl 2005). Using a lifespan of 15 years, the predicted survival rates for both sexes are around 70 to 80% (Davis et al. 1962).

Threats

The Brazilian free-tailed bat is especially vulnerable to habitat destruction and human disturbance due to its tendency to roost in large numbers at relatively few roost sites (Lowery 1974, Humphrey 1992). Population declines of the Brazilian free-tailed bat have been reported over the last 50-100 years in the US, potentially due to the destruction and disturbance of large roosting colonies such as maternity sites, as well as direct or indirect poisoning by pesticides and heavy metals (McCracken 1986, Gannon et al. 2005). Pesticides may alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Because this species consumes large amounts of crop pests, they may have an increased risk of contamination from the accumulation of organochlorine pesticides in their body fat. During migration when fat is metabolized, exposure to these pesticides is increased and can be lethal (Bennett and Monte 2007). Young bats are particularly susceptible to pesticides through their mother's milk and post-weaning diet (Clark et al. 1975).

Dynamiting, burning, and guano mining have also caused complete loss of some maternity roosts in the US and Mexico. Housing development, vandalism, wind turbines, pollution, and climate change may also threaten roots with the highest risk to bat populations that reside in Bracken Cave, Congress Avenue Bridge, and Davis Cave in Texas (Svancara et al. 2014).

Wind energy development is a major threat, as large numbers of Brazilian free-tailed bats have been killed from wind turbine collisions. Piorkowski and O'Connell (2010) showed a steady rate of collision mortality of this species at the Oklahoma Wind Energy Center, and reported that of the seven bat species killed by wind turbines, 85% of all bat fatalities were Brazilian free-tailed bats. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to Brazilian free-tailed bats, eviction from buildings should include appropriately timed exclusion methods. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). To avoid the maternity period, bats should not be evicted from May through July.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Researchers are requested to collect and record bat data, but the SCDNR Heritage Trust does not track this species in its database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Eastern Red Bat (*Lasiurus borealis*)

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Description

The eastern red bat is distinctive in its remarkable bright red to rusty-red pelage, and is known to be the most abundant foliage roosting bat in North America. Their unique color is a form of camouflage that mimics dead leaves or pinecones as they hang, wrapped by their furry tail membrane in the foliage of trees. Unusual in bat species, males and females seem to differ in color, with males being brighter red than females. However, this characteristic might be linked more to body size than sex (Davis and Castleberry 2010). Eastern red bats are a solitary foliage roosting species and do not hibernate in caves. Instead their thick insulative skin, heavily furred uropatagium, and short, rounded ears assist in minimizing heat loss while hibernating in trees. Unfortunately, the eastern red bat is one of the most frequently reported bat species found dead at wind turbine facilities in North America (Ellison 2012).

Identification

This species is a medium sized bat that weighs 0.3 to 0.5 ounces (9 to15 gr) and has a wingspan of 11 to 13 inches (28 to 33 cm) (Harvey et al. 2011). The brick red fur is soft and fluffy with some hairs tipped with white (more so in females and juveniles), and a buffy white patch on the front of the shoulders. The ears are broad, rounded and low on the head, and the tragus is triangular. The wings of eastern red bats are long and pointed, and the dorsal side of the uropatagium is covered in thick fur. Their skull is short, broad and heavily constructed.

Taxonomy

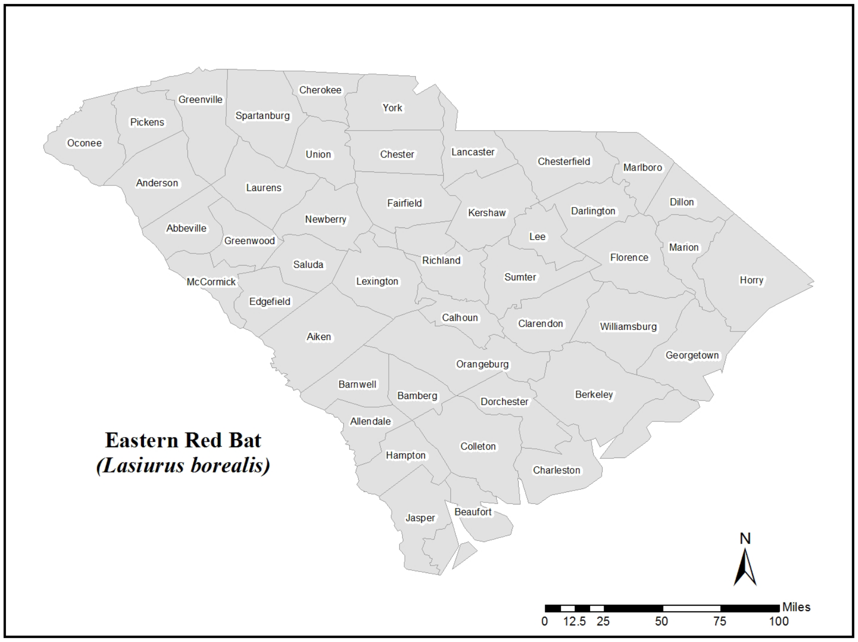
Though a number of subspecies were once recognized (Shump and Shump 1982*b*), the eastern red bat is now considered monotypic (Wilson and Reeder 2005).

Distribution

Eastern red bats are distributed throughout southern Canada, into the eastern US (but not the Florida peninsula), and southward into northeastern Mexico, Argentina and Chile. In the US, their range extends west to the Midwestern and east-central states (Shump and Shump 1982*b*, Harvey et al. 2011). In the winter, this species migrates to southern states and is found from southern Illinois and southern Indiana south (Whitaker and Hamilton 1998). In South Carolina, eastern red bats are common statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003).

Population Status

Common and abundant through most of its range, the eastern red bat G has a rounded rank of lobally Vulnerable (G3G4), Nationally Secure (N5) and Subnationally unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Apparently Secure (S4S5) by the SCDNR Heritage Trust (see Table 2). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales et al.



2008*a*). This species is considered locally common, but is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015) due to severe WNS-related mortality occurring in other bat species, and the fact that *P.d.* has been detected on eastern red bats but no diagnostic sign of WNS has been documented.

General Habitat

Occurs throughout forested habitat of the eastern US, and is partial to elm trees (*Ulmus* species), wooded hedgerows, and large shade trees in urban areas such as those found in city parks (Mager and Nelson 2001). In South Carolina, habitat types used in the home range of five eastern red bats tracked at the Savannah River Site included 55% bottomland hardwoods, 40% pine stands, and 5% upland hardwoods (Carter 1998). Additionally, sparse vegetation was found to be the best predictor of habitat use by eastern red bats (Loeb and O'Keefe 2006).

Roosts and Roosting Behavior

Eastern red bats are a solitary roosting species found mainly in trees and shrubs, as well as near or on the ground (Hall and Kelson 1959), as well as in Spanish moss (*Tillandsia usneoides*) (Constantine 1958). Day roosts are often in areas of edge habitat adjacent to open fields, streams, and in urban areas (Shump and Shump 1982*b*).

During summer, eastern red bats are usually found roosting on leaf petioles and small branches in the tops of deciduous trees (Barbour and Davis 1969), though they may also be found in caves (Myers 1960), woodpecker cavities (Fassler 1975), leaf litter (Moorman et al. 1999), dense grass, and shingles of houses (Mager and Nelson 2001). Mager and Nelson (2001) found 89 % of roosts were in foliage or the trunks of deciduous trees greater than 18 inches (45 cm) dbh. Though eastern red bats are often found roosting in deciduous trees, Elmore et al. (2004) found that within thinned pine stands of intensively managed pine landscapes in Mississippi, 70% of their day roosts were found in 16 species of hardwood trees and 30% in loblolly pines. Also, preferred roosts were located within denser subcanopy and higher basal area, but specific tree characteristics were not as important as those at the stand-level. Nonreproductive eastern red bats in the southern Appalachian Mountains also did not select roosts based on tree or microhabitat characteristics and used a wide range of stand conditions and ages (O'Keefe et al. 2009). At the Savannah River Site in South Carolina, roosts were found in 23 total tree species, and sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*) were used most (Menzel et al. 2000*a*). In the same study, compared to random plots, roost trees were found in stands with larger basal areas, higher and denser overstory, and more diverse overstory and understory. Roost sites were switched often, with an average of 1.2 nights spent at each tree (Menzel et al. 1998). Frequent roost switching may be a response to changing microclimate conditions at different trees (Kunz 1982*b*). The mean maximum distance between locations for three eastern red bats in the southern Appalachian Mountains was 1,476 ± 298 feet with a range of 6.8 to 2,744 feet (450 ± 91 m; range 2.1–836.5 m) (O'Keefe 2009). Though this species has low roost site fidelity, they are known to have high site fidelity and thus commonly roost within the same general area (Hutchinson 1998, Mager and Nelson 2001). Eastern red bats may forage in close association with each other during summer, and different individuals often use roost sites on different days (Constantine 1966, Downes 1964). In Illinois, large trees in urban areas were found to be extremely important roosting sites for eastern red bats in an otherwise fragmented landscape (Mager and Nelson 2001). In a study in Iowa, McClure (1942) found roosts in dense shade and cover on the south side of trees at a height of between 3.6 to 10.2 feet (1.1 to 3.1 m) to be preferred. However, the majority of roosts found by Mager and Nelson (2001) in central Illinois were located on the north or east side of trees at a height greater than 16 feet (5 m). In South Carolina, female eastern red bats have been found to select trees on north and northwest facing slopes (Leput 2004), and roosts in Georgia and South Carolina forests were found at an average height of 50 feet (15.3 m) (Menzel et al. 1998).

Females roost separately with young in tree foliage instead of in colonies. When found in family clusters, the preferred height of the roost site increased from 10.2 to 20.3 feet (3.1 to 6.2 m) (McClure 1942). During summer, females have higher temperature demands for birthing and nursery conditions, and seem to be restricted to lower elevations associated with higher temperatures in the eastern US (Ford et al. 2002). As family groups broke up, young continued to occupy higher roosts compared to adults who appeared to have no preference (Constantine 1966).

In the fall in the South Carolina, eastern red bats have been seen flying out of leaf litter ahead of prescribed burns (Moorman et al. 1999).

During winter, eastern red bats are commonly found in leaf clusters and tree branches, though some hibernate in old squirrel nests, leaf litter, and Spanish moss (Constantine 1958, Barbour and Davis 1969, Saugey et al. 1989). Northern populations migrate south for the winter, but most eastern red bats in South Carolina are considered resident. However, the winter habits of eastern red bats are not well known in the state. This species may become torpid at temperatures below 69°F (20°C), and survives subfreezing temperatures by maintaining body temperature just above the critical limit of 23°F (-5°C) (Reite and Davis 1966). Eastern red bats were found actively feeding throughout the year in southeastern Virginia and northeastern North Carolina at temperatures above 48°F (9°C) (Padgett and Rose 1991, Whitaker et al. 1997). Similar to bats considered true hibernators, eastern red bats may lose 25% of their pre-hibernation body weight by spring (Fenton 1985). According to Whitaker and Hamilton (1998), males and females have separate winter and summer ranges and migrate at different times. However, in California males and females have been found to winter together (Williams and Findley 1979).

Reproduction

Copulation may be initiated in flight (Stuewer 1948), and mating occurs between August and September (Glass 1966, Whitaker and Hamilton 1998). Sperm is stored in the female's uterus until spring when fertilization takes place. The mother gives birth from one to five young (average of two) in late May to mid June or July, and has four mammary glands instead of two found in most bats (Shump and Shump 1982*b*). Gestation lasts 80 to 90 days (Jackson 1961), lactation lasts 38 days (Kunz 1971), and young are weaned between four to six weeks and begin to fly between three to six weeks (Hamilton 1943, Jackson 1961, Barbour and Davis 1969). Males and females of this species mature relatively early compared to many South Carolina bat species as they are sexually mature by their first autumn (Cryan et al. 2012).

Food Habits and Foraging

Eastern red bats usually begin to forage about one to two hours after sunset, with the most active foraging periods corresponding to the initial, and later the increased, nocturnal activity of insects (Kunz 1973), though nursing adult females may feed all night. With a high aspect ratio and high wing loading, this species is only moderately maneuverable and can fly relatively fast (Shump and Shump 1982*b*). Eastern red bats may travel between 1,600 to 3,000 feet (500 to 900 m) from day roosts to feeding sites (Jackson 1961). The distance traveled while foraging is around 0.25 to 3.2 miles (0.4 to 5.5 km), and the foraging speed of this species is around 15 miles per hour (24 kmph) on average (Naughton 2012).

Eastern red bats may forage at or above treetop level (Schmidly 1991), over water such as lakes or streams, habitat edges (Furlonger et al. 1987), open habitats, in cypress stands, and around lights where they may land on light poles to catch moths (Barbour and Davis 1969, Hickey and Fenton 1990). However, the activity of this species did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005) despite being considered a clutter-adapted species. In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of eastern red bats to be significantly higher in thinned tree stands compared to control or burned stands. At the Savannah River Site, Carter (1998) found the average home range for this species to be 1,119 acres (453 ha), and the habitat types within the home range were 55% bottomland hardwoods, 40% pine stands, and 5% upland hardwoods. In the Coastal Plain of South Carolina, foraging activity was mostly over riparian areas, wetlands, and bottomlands in both cluttered and uncluttered habitats (Menzel et al. 2005*b*, *a*). The activity of eastern red bats has been recorded widely around Lake Jocassee and Lake Keowee in the state, and was found in 30 of the 31 sites surveyed in April, July, and October (Webster 2013).

Eastern red bats have been found to consume Coleoptera, Diptera, Hymenoptera, Homoptera, Lepidoptera, and Orthoptera, which includes specific insects such as ground-dwelling crickets, cicadas, and grain moths (Connor 1971, Hamilton 1943, Jackson 1961, Lewis 1940). In Indiana, the diet of this species consisted of 26.2% moths and 28.1% beetles, with the rest including June bugs, ants, and leafhoppers (Whitaker and Hamilton 1998). In early summer in South Carolina, eastern red bats generally feed on Coleoptera and Hemiptera, and as the summer continues may add Lepidoptera, Homoptera, and Hymenoptera to their diet (Carter 1998, Donahue 1998, Carter et al. 2004). During winter in North Carolina, this species is seen actively feeding on moths and flies, generally at temperatures above 48°F (9°C) (Padgett and Rose 1991, Whitaker et al. 1997). On average, Hickey et al. (1996) found that eastern red bats in Ontario attack insects every 30 seconds and are successful 40% of the time.

Seasonal Movements

Considered highly migratory, this species tends to migrate in groups despite normally being a solitary roosting species (LaVal and LaVal 1979, Shump and Shump 1982*b*). Eastern red bats migrate from northern states to the southern US to hibernate (M. A. Menzel et al. 2003). However, in South Carolina eastern red bats are considered year round residents, and their numbers increase in late fall and winter as winter migrants arrive.

Longevity and Survival

The maximum life span of the eastern red bat has been estimated at 12 years (Saunders 1988).

Threats

Populations of this species may have substantially declined in the last century, as there are reports of much larger flocks seen in the 1800s (Bat Conservation International 2015). More recently, a study in Michigan by Winhold (2008) found that the number of eastern red bats captured had decreased between 52 to 85% in a 12 to 26 year period.

At wind turbine facilities in North America, the eastern red bat is one of the most frequently found dead, and one of the top species recorded with the most bat fatalities (Ellison 2012). For example, Fiedler (2004) found that 61.3% of the bat fatalities at a wind farm in eastern Tennessee were eastern red bats, where the overall bat mortality rate for the site was 20.8 bats/turbine/year. Because the eastern red bat is one of three migratory tree bats that compose the majority of wind turbine fatalities, it has been suggested that seasonality and migration patterns make them more vulnerable to collisions (Cryan 2011). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Large buildings also pose a collision threat to eastern red bats. Timm (1989) reported that 50 individuals struck the large glass windows of one convention center in Chicago over an 8-year period. Forty-eight of those individuals were collected during the fall, suggesting that the bats hit the building during migration. Small numbers of deadly collisions with towers in Florida have also been recorded (Crawford and Baker 1981).

WNS has the potential to be a threat as it has been detected on eastern red bats, but they have not yet shown diagnostic sign of the disease (White-nose Syndrome.org 2015).

Prescribed burning in the fall may also pose a threat to eastern red bats since they are found hibernating in leaf litter in South Carolina during this time (Moorman et al. 1999).

Habitat and roost site loss due to development and removal of palm fronds are other potential threats for this species (Bunch et al. 2015*c*). The harvesting of Spanish moss may still be a threat in some areas, but the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). Additionally, foraging habitat may be reduced by increased urbanization, loss of riparian habitat, and grazing. Many of these forms of habitat alterations can also cause increased predation by natural predators. Also, natural causes such as hurricanes may also create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Conservation Measures

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*b*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to eastern red bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); retain and encourage retention of Spanish moss and old palm fronds on public lands; and timber management in the Piedmont region that includes pine thinning or controlled burns may benefit this species by creating more open forest areas. Other measures may include working to maintain hedgerow habitats along crop borders; retain large trees in urban areas; minimize or carefully consider large-scale pesticide use whenever possible; and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to better understand winter roost site and habitat requirements of eastern red bats; gather migration information for eastern red bats; determine the extent and seasonality of off-shore commuting and foraging to assess vulnerability of eastern red bats to off-shore wind development; and determine the vulnerability of eastern red bats, especially during fall migration, to coastal wind energy development. Other recommendations might include research to better understand population status, summer roost sites, and behavior of this species. The SCDNR Heritage Trust tracks high priority species including the eastern red bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; and discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees.

Eastern Small-footed Bat (*Myotis leibii*)

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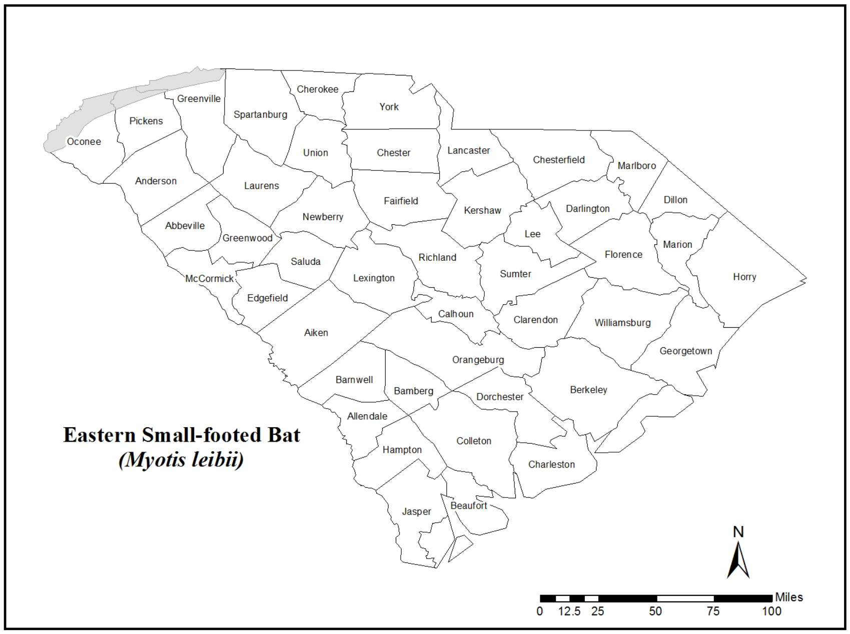
Description
The eastern small-footed bat is the smallest bat in South Carolina. It is also one of the smallest and rarest bats in North America, despite having a wide distribution in the northeast. Most small rodents of this size only live around 1.5 years, but the eastern small-footed bat may live eight times longer. This species is known for its ability to tolerate colder temperatures than most bats, and it hibernates for a relatively shorter period during winter. Its slow, erratic flight is characteristic enough to identify this bat in the field. Unfortunately the eastern small-footed bat is extremely susceptible to WNS, and according to Alves et al. (2014), an expected relative population reduction is estimated to be 71.2% in an intermediate population-reduction scenario (compared to a pessimistic scenario at 96.6%, and an optimistic scenario at 29.3%). An eastern small-footed bat was first discovered suffering from WNS in South Carolina at Table Rock State Park in 2013.

Identification
The eastern small-footed bat weighs 0.01 ounce (3 to 4 grams) and has a wingspan of 8 to 10 inches (21 to 25 cm) (Harvey et al. 2011). This species is a small brown bat with a black mask, black ears, and distinctively small feet measuring only 0.2 to 0.3 inches (6 to 8 mm). The pelage is black at the root with glossy brown on the tips, and is dark on the back and whitish to buff on the belly. The wing and tail membranes, as well as the muzzle, are a dark chocolate color. This species has short, broad wings with rounded wingtips.

Taxonomy
The eastern small-footed bat is considered monotypic (Wilson and Reeder 2005).

Distribution
This species is distributed from eastern Canada and New England southwest to southeastern Oklahoma, Arkansas, and southeast to northern Alabama, northern Georgia, and northwestern South Carolina. In South Carolina, eastern small-footed bats are limited to the extreme northern portion of the Blue Ridge region (M. A. Menzel et al. 2003).

Population Status
Considered uncommon through most of its range, the eastern small-footed bat is ranked as Globally Apparently Secure (G4), a rounded rank of Nationally Vulnerable (N3N4), and is Subnationally ranked as Critically Imperiled (S1) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*a*). This species has never been regarded as abundant anywhere, and population trends are largely unknown. This may be in part because they're overlooked in cave surveys due to solitary roosting at inconspicuous sites (Krutzsch 1966, Dunn and Hall 1989). In South Carolina the eastern small-footed bat is listed as a Highest Priority species in the South Carolina 2015 SWAP, and is designated as "in need of management" which equates to state



threatened (SCDNR 2015). In October 2013, the USFWS determined that the species did not warrant listing under the Endangered Species Act (USFWS 2013).

General Habitat

This species is found in mostly hilly or mountainous regions, in or near deciduous or evergreen forest, bottomland, floodplains, and sometimes in mostly open farmland (Arroyo-Cabrales and Álvarez-Castañeda 2008*a*, Bunch et al. 2015*b*). In Pennsylvania, this species was found in the foothills of mountains with an elevation of 2,000 feet (600 m) mostly in heavy hemlock forests (Mohr 1932). They have also been found at elevations of (675 m) in Georgia (Baker 1967, Baker and Patton 1967), (750 m) in Virginia (Johnson 1950), and (1,125 m) in Kentucky (Barbour 1951).

Roosts and Roosting Behavior

Overall, this species has been found in buildings, expansion joints of bridges, cliff crevices, caves, mines, towers, hollow trees, spaces beneath loose tree bark, and under the loose tarpaper of an old house.

In summer, eastern small-footed bats are known to use ground level rock roosts in talus slopes, rock fields and vertical cliff faces (Johnson et al. 2011), behind the door of a shed in Ontario (Hitchcock 1955), in limestone caves (Krutzsch 1966), under large flat rocks at the edge of quarries (Tuttle 1964), and beneath the bark of trees (Barbour and Davis 1969). The ceilings of caves are used as night roosts (Davis et al. 1965). Roost sites are often changed, sometimes daily, by both males and females of this species (J. S. Johnson et al. 2008). Non-reproductive females and males roost individually during summer, and during the breeding season males have been captured at entrances of caves, abandoned mines, and railroad tunnels (Amelon and Burhans 2006*b*). In South Carolina, eastern small-footed bat roosts have been found in a woodpile on a porch, a fish hatchery building, and a picnic shelter (Bunch et al. 2015*b*). There is also a spring record of a lone male found under loose tarpaper of an abandoned log cabin in Pickens County (Bunch and Dye 1999*a*). However, spring and summer roosts of eastern small-footed bats are largely unknown in South Carolina.

Roosts of maternity and nursery colonies of up to 33 bats have been reported in a cabin in North Carolina (O'Keefe and LaVoie 2011), behind loose bark in trees (Tuttle 1964), under exposed rocks on open ridges, and in the expansion joint of a concrete bridge (MacGregor et al. 1999). Reproductive females tend to choose maternity colony sites with high solar exposure, which is thought to decrease energy expenditure, provide thermal stability for young, and foster rapid offspring growth rates (Harvey and Redman 2001, Johnson and Gates 2008). Another factor in maternity site selection may be proximity to water (MacGregor and Kiser 1998). No maternity colonies have been located in South Carolina.

During winter, the eastern small-footed bat is one of the last to enter hibernacula and one of the first to leave, as they seldom enter before mid-November (Godin 1977, Gunier and Elder 1973,) and depart by early March (Mohr 1936). This species can be found hibernating in solution and fissure caves and mine tunnels, and usually prefers areas near the entrance where temperatures drop below freezing and the air is relatively dry (Barbour and Davis 1969, Gunier and Elder 1973). However, individuals will arouse from torpor and move to warmer locations, such as deeper inside caves, when temperatures fall below 15°F (-9°C) (Naughton 2012). Eastern small-footed bats are often found hibernating horizontally in narrow crevices and under rocks on the cave floor, or hanging from the wall or ceiling of the cave or mine (Davis 1955, Martin et al. 1966, McDaniel et al. 1982). They are also known to use shallow caves, and in Pennsylvania 52% of hibernacula identified were small caves of less than 500 feet (150 m) (Dunn and Hall 1989). In South Carolina, the winter roosting habits of this species are unknown, though an individual of undetermined sex in a rock outcrop crevice in mature hardwoods was recorded during winter in the mountains of Pickens County (Bunch and Dye 1999*a*). Eastern small-footed bats have high site fidelity to hibernacula and return to the same site each year (Gates et al. 1984). This species usually hibernates individually, but may also be found in small clusters. The largest hibernating colony discovered was that of 142 individuals in Ontario in February (Hitchcock 1949). Compared to other cave-hibernating species this bat is relatively active during hibernation, moving within and among hibernacula (Mohr 1942), and evidence indicates this species may not spend as much time in deep torpor (Mohr 1936, Hitchcock 1946, Tuttle 1964). These periodic arousals may be necessary to enhance immune function (Luis and Hudson 2006) and obtain enough water (Thomas and Geiser 1997).

Reproduction

Not much information about reproduction has been published for this species, though it is thought that it is similar to that of the little brown bat (*Myotis lucifugus*). Swarming to choose a mate occurs from late summer to early fall. Based on one reproductively active male found in September (Saugey et al. 1993), copulation probably occurs in the fall and the sperm is stored in the uterus of the female until spring. Gestation may last around two months, and a single pup is born in May or June (Peterson 1966, Barbour and Davis 1969, Godin 1977). It has been theorized that this species only gives birth to a single pup because the weight of more than one may be too great of a burden for the female to carry (Hitchcock et al. 1984), as the pup is 20 to 35% of the female's body weight (Kleiman and Davis 1979). According to anecdotal evidence form Hobson (1998), females may fly with newborns as early as June.

Food Habits and Foraging

Emerging at dusk shortly after sunset, the eastern small-footed bat flies slowly around a height of one to 10 feet (0.3 to 3 m) (Davis et al. 1965, Barbour and Davis 1969, van Zyll de Jong 1985), usually over water such as ponds and streams (MacGregor and Kiser 1998), but also in forest understory and canopy (Merritt 1987, Linzey 1998, Harvey et al. 1999*a*) and open fields (Neuhauser 1971). Because this species has short, broad wings and rounded wingtips, they are extremely maneuverable in dense vegetation (Norberg and Rayner 1987).

In South Carolina, they have been seen foraging over Reedy Cove Creek greater than 330 feet (100 m) downstream from the waterfalls (Bunch et al. 2015*b*). Activity of eastern small-footed bats has also been recorded at Eastatoe Creek and the northern reaches of Lake Jocassee, at nine of the 31 sites surveyed in April, July, and October (Webster 2013).

The diet of the eastern small-footed bat consists mainly of flying insects from Lepidoptera, Diptera, and Coleoptera (specifically moths, flies, and small beetles) but also consume Araneae and Orthoptera (spiders and crickets) (Moosman et al. 2007). When insects are abundant, this species may fill their stomach within an hour of the beginning of their foraging bout (Norberg and Rayner 1987). Eastern small-footed bats capture their prey while in flight or by gleaning prey off of a surface (Moosman et al. 2007).

Seasonal Movements
Eastern small-footed bats are commonly found in late summer flocks of migrating bats, but where they reside in other seasons is somewhat unknown (Barbour and Davis 1969). Migration may happen in late winter after eastern small-footed bats leave their hibernacula (Mohr 1933). However, this species may not undertake long migrations to hibernacula but hibernate near their summer range (van Zyll de Jong 1985). For example, two bats banded in an Ontario cave were reported to have not moved farther than about 12 miles (20 km) a few months later (Naughton 2012). Additionally, three females have been known to migrate 0.06 to 0.68 miles (0.1 to 1.1 km) to rocky outcrops within shale barren habitat from their winter hibernacula (Johnson and Gates 2008). The local availability of suitable habitat may play a large role in the distance this species migrates.

Longevity and Survival
An individual of this species is reported to have lived 12 years in the wild (Hitchcock 1965). The survival rate of eastern small-footed bats is thought to be relatively low. Based on banding data, the estimated mean annual survival for males is 0.76 years and for females is 0.42 years (Hitchcock et al. 1984).

Threats
Eastern small-footed bats are particularly vulnerable to external threats due to life history traits that make it slow to recover, such as a diffuse distribution, small population size, and low fecundity (USFWS 2011).

WNS threatens eastern small-footed bats as it has caused up to 100% mortality in some bat populations (Kunz and Tuttle 2009). WNS has been confirmed across large portions of the eastern small-footed bats' range, and sampled populations in New York, Massachusetts, and Vermont had already declined 78% overall between 2006 and 2009 (Langwig et al. 2009). According to Alves et al. (2014), an expected relative population reduction for this species is estimated to be 71.2% in an intermediate population-reduction scenario, compared to a pessimistic scenario at 96.6%, and an optimistic scenario at 29.3% population reduction. In the event of pessimistic and intermediate scenarios, this species will be considered Critically Endangered. Eastern small-footed bats are also at a greater risk of infection by WNS due to their tendency to roost near the entrance of hibernacula where exposure may be increased.

Disturbance and vandalism of hibernacula by human activities poses another large threat for this species (Tuttle 1979, Thomas et al. 1990, Caceres and Pybus 1997). Destruction of hibernacula is the main factor in population declines of bat species dependent on caves and mines (Humphrey 1978, Sheffield and Chapman 1992). Mine closures cause direct mortality to this species if they occur during hibernation. Even closing mines during non-hibernating periods forces eastern small-footed bats to burn critical fat reserves while searching for new hibernacula.

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Eastern small-footed bats may be particularly vulnerable to environmental contaminants due to their association with mining activities and small size (Amelon and Burhans 2006*b*).

Eastern small-footed bats are vulnerable to habitat loss associated with natural resource exploitation due to their reliance on loose shale, talus, or karst formation often found in oil, gas, and mineral rich areas (Amelon and Burhans 2006*b*).

Because this species tends to roost in talus areas occurring on ridge tops, wind power development may adversely affect the eastern small-footed bat through habitat loss from construction (Amelon and Burhans 2006*b*). Bat mortality from turbines may also pose a threat, but this species is probably less vulnerable than other bats due to its low-flying habits. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Another threat to this species is the inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011). Many of forms of habitat alterations may also increase predation by natural predators.

Global climate change may be a potential threat to eastern small-footed bats, since (like all bats) they depend highly on temperature for important processes such as hibernation, reproduction, and growth. A change in climate may also make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*). This threat has the potential to cause eastern small-footed bats to deplete energy reserves through more frequent arousal from torpor since this species hibernates in areas more susceptible to fluctuations in temperature than those that hibernate in the cave interior (Humphries et al. 2002, Rodenhouse et al. 2009). Continued change in temperature and precipitation may also affect this species indirectly by changing the availability of their insectivorous prey (Bale et al. 2002).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to eastern small-footed bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and

Fenton 1971). Measures should be taken to provide species-specific alternate roost structures in the event of a disturbance, such as multi-chamber nursery boxes for eastern small-footed bat colonies.

Recommendations from NatureServe (2015) state that caves and mines which serve as hibernacula should be protected during the hibernation period from November through March, and include a buffer zone to protect from disturbances such as logging that might change water and airflow, temperature, and humidity. Additionally, maternity colony roosts and surrounding habitat should be protected during late spring and early summer, with adjacent foraging areas protected from deforestation. Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include working to determine feeding patterns and summer and winter roost site requirements for eastern small-footed bats; determine if prescribed fire represents any threat, and what the acceptable distances are of fire, smoke and fire lines from roosts; identify colonies and monitor colony size, persistence, and roost sites long term; conduct seasonal surveys at caves and mines being considered for closure; evaluate roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the eastern small-footed bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Evening Bat (*Nycticeius humeralis*)

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Description

The evening bat is a medium sized bat with dark brown pelage above and paler below, generally with light ash-gray hair tips on the dorsal area. According to Kurta (2001), a common agricultural pest eaten by this species is the corn rootworm, and 1.25 million insects can be consumed in a single season by 100 evening bats. Also, females produce a litter that is the largest in relation to maternal size of all bats, which is 50% of her postpartum body mass. This species resembles many other bats from the *Myotis* genus and the big brown bat, but misidentification is avoided by the identification of the two upper incisors versus the four in *Myotis* species and the big brown bat, as well as the characteristically rounded, curved tragus found in evening bats. Additionally, evening bats can be separated from the big brown bat by their smaller size and absence of a keel on the calcar (Barbour and Davis 1974).

Identification

Evening bats weigh 0.2 to 0.5 ounces (7 to 14 gr) and have a wingspan of 10 to 11 inches (26-28 cm) (Harvey et al. 2011). This species has a short, broad skull and the ears are short and rounded. The pelage is dark brown to blackish-brown on the upper side, and slightly lighter in color on the lower. The uropatagium on evening bats is furred at the base, but the dark brown-black ears, nose, and the rest of the wing membranes are hairless. Sexual dimorphism exists in the evening bat, with females consistently heavier than males.

Taxonomy

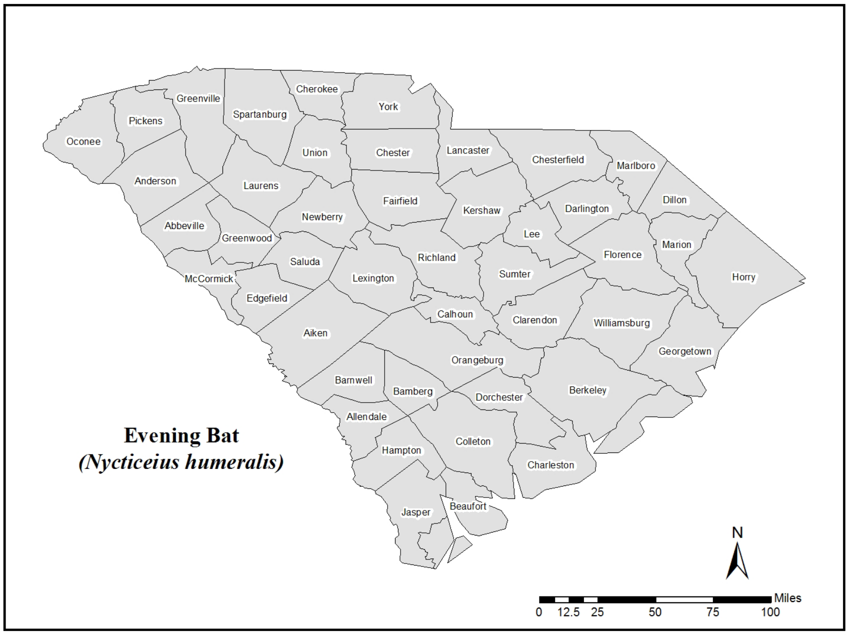
Currently there are three recognized subspecies of the evening bat (Wilson and Reeder 2005), and only *Nycticeius humeralis humeralis* has been confirmed in South Carolina (Hall 1981).

Distribution

The evening bat is found throughout most of the eastern US and northeastern Mexico. It ranges north from Nebraska, Iowa, southern Michigan, Pennsylvania, and New Jersey to west in Kansas and eastern Texas, and south to Veracruz, Mexico. In the southern Appalachians this species is rare or absent (Barbour and Davis 1974, Webster et al. 1985). In South Carolina, it is common throughout the majority of the state and occurs in all physiographic provinces (M. A. Menzel et al. 2003).

Population Status

Less common throughout most of its range, in the southern coastal states the evening bat is one of the most common bat species (Harvey et al. 2011). This species is ranked as Globally Secure (G5), Nationally Secure (N5), and Subnationally unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally secture (S5) by the



Evening Bat
(Nycticeius humeralis)

SCDNR Heritage Trust (see Table 2). The evening bat is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*b*). It is considered locally common and is not listed as a Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

General Habitat

Historically, evening bats were probably associated with bottomland forests, swamps, and wetlands (Amelon and Burhans 2006*c*). Today they are a forest dwelling species that inhabit eastern deciduous forests at elevations from sea level to 980 feet (300 m) (Watkins 1972), and are commonly found along waterways (Schmidly 1991).

Roosts and Roosting Behavior

The evening bat prefers to roost in hollow trees, the underside of loose bark, or in buildings (Barbour and Davis 1969, Chapman and Chapman 1990, Menzel et al. 2001*a*). In Florida, evening bats have also been found in Spanish moss (*Tillandsia usneoides*) (Jennings 1958) and underneath palm fronds (Taylor and Lehman 1997). This species rarely roosts in caves as only one record of cave roosting has been reported in Missouri (Easterla 1965).

During summer, evening bats selected roost sites differently based on landscape conditions in Georgia. Day roosts selected on the natural site were based on tree, plot, and landscape characteristics, but on the managed site bats selected day roosts at the tree and plot scale (Miles et al. 2006). In southwestern Missouri, evening bats selected trees in late stages of decay (Boyles and Robbins 2006). At the Savannah River Site in South Carolina, roosts were in cavities or under exfoliating bark most commonly found in longleaf pines (*Pinus palustris*), though conifer snags in beaver ponds were also common. Menzel et al. (2000) also reported that, compared to random plots, roosts were found in areas where the canopy was taller and less dense, there was greater snag abundance, the overstory had less trees and lower richness, and the understory had less trees, lower richness and lower diversity. In the lower coastal plain of South Carolina, evening bats roosted in cavities in hardwood trees and fork-topped loblolly pines (*Pinus taeda*), with both male and female evening bats selecting roost sites in mixed-pine hardwoods (Hein 2008). Also in this study, about 40% of male and 20% of female roosts were located in forested corridor stands.

Nursery roosts may be located in hollow cypress trees, behind the loose bark of dead pines, in Spanish moss, and in buildings and attics (Jennings 1958, Cope et al. 1961, Watkins and Shump 1981, Menzel et al. 2001*a*). Nursery colonies may vary from 25 to 950 individuals (Watkins 1969). Adult males are not present in these colonies, and male offspring disperse from the nursing colony before females (Watkins and Shump 1981, Bain and Humphrey 1986). Roosts in attics vary from 46° to 113°F (8° to 45° C) when nursery colonies are present, and individuals are known to spread out at higher temperatures (Watkins 1972). In South Carolina, Menzel et al. (2001) found that evening bat maternity colonies used mature longleaf pine stands with a higher overstory, greater canopy density, and greater proportion of basal area composed of conifers compared to roosts used by solitary evening bats surrounding the maternity colony. Of the 33 maternity colonies found in South Carolina by Hein (2008), 15 smaller colonies of 4 to 27 bats were in fork-topped trees and 18 larger colonies of over 22 bats were found in tree cavities. Also, four of the cavity trees had greater than 50 individuals, and two of these had over 100.

Not much is known about the winter habitat of the evening bat in southern states. In southwestern Missouri, Boyles and Robbins (2006) reported differences in tree versus habitat-level roosts between seasons, and that habitat characteristics were more important than tree characteristics in explaining this variation. During winter in this study, this species selected a higher proportion of live trees than in summer, and trees were located in areas with lower average tree height and higher densities of trees. The northern breeding populations of evening bats may migrate south for the winter, as males and females are found in southern states during this time from South Carolina to Arkansas (Watkins 1972), and it is thought that they are active during warm periods. However, winter roosting habits in southeastern states, including South Carolina, have not been described (Whitaker and Hamilton 1998). In Florida, evening bats have been known to use buildings as winter roosts (Bain 1981). In South Carolina, there have been winter records of this species in attics in Charleston County (M. A. Menzel et al. 2003).

Reproduction

The sexes segregate during the reproductive period for this species (Watkins 1972). Mating occurs in the fall, and in Florida it beings in October and occurs throughout winter (Bain and Humphrey 1986). Sperm is stored in the female's uterus until spring when fertilization takes place. Adult females arrive at nursery roosts around the second week of April in South Carolina (Golley 1966). In the south, the birth of one to three pups (average of two) occurs from the middle of May to the middle of June (Watkins 1972). A higher rate of growth of the young tend to occur in smaller, crowded roosts (Watkins 1972). Some evening bat females are known to nurse offspring that are not their own, and it has been hypothesized that this may be a way of getting rid of excess milk (Wilkinson 1992). Young begin to fly by three weeks, reach the size of an adult within a month, and are weaned between six to nine weeks (Jones 1967, Schmidly 1991). By late August, most individuals have left their nursery colonies (Baker 1965). It has been reported that juvenile males are reproductively mature at less than one month old (Bain and Humphrey 1986). However, in a study conducted by Millis (2013), the average age at sexual maturity for males born before mid-July was about four months old. It is unknown when females reach sexual maturity, though like other temperate bat species, they may build fat reserves during the first year instead of entering the reproductive population (Burnett and Kunz 1982).

Food Habits and Foraging

Evening bats emerge from their roosts relatively early, leaving around dusk (Lowery 1974). For this species, foraging activity peaks in the early evening, and again just before dawn (Watkins 1971). They have a steady, slow flight, and begin at a height of about 43 to 82 feet (13 to 25 m), flying much closer to the ground as night falls (Harper 1927, Lowery 1974). Though they are considered a clutter-adapted species, a substantial amount of foraging activity still happens above, compared to below or within, forest canopy, in South Carolina (Menzel et al. 2005*b*).

Wetlands, bottomlands, and riparian areas are the primary foraging habitat of this species (Menzel et al. 2002, Schmidly 1991). In Georgia, 76% of foraging habitat was over slash-loblolly pine (Krishon et al. 1997). At the Savannah River Site in the Upper Coastal Plain of South Carolina, evening bats were found using pine savannahs (Ford et al. 2006*a*), as well as in gaps in bottomland hardwood and swamp forests, and over beaver ponds (Menzel et al. 2001*a*). Menzel et al. (2005) found riparian areas were more actively used than upland habitat. In a study by Carter (1998), habitat types within home ranges of six evening bats were used in the same proportion that they were available, and included pine forests and bottomland hardwoods. Carter et al. (2004) found that evening bats were most active in pine forests (59%) and bottomlands (37%) and rarely foraged in upland hardwoods. Menzel et al. (2003) found most evening bat activity over Carolina bays, as well as grassy areas and bottomland hardwoods. Additionally, activity was highest in clearcuts and young stands, moderate in stands greater than 60 years old, and lowest in stands between 21 to 60 years old. The activity of evening bats has also been recorded at nine out of 31 sites around Lake Jocassee and Lake Keowee in the spring and summer, but not in the fall, suggesting migration northwestward into the Upper Piedmont in spring and southeastward migration out of the Upstate in fall (Webster 2013).

Evening bats feed on Coleoptera, Diptera, Hymenoptera, Hemiptera, Homoptera, and Lepidoptera, which specifically include June beetles, Japanese beetles, flying ants, spittle bugs, and moths (Ross 1967, Mumford and Whitaker 1982, Feldhamer et al. 1995, Carter 1998, Bat Conservation International 2015). In South Carolina, Carter found that in midsummer this species feeds primarily on Coleoptera and Hymenoptera, and in later summer consumes Hemiptera and Homoptera as well (Carter 1998, Carter et al. 2004). One evening bat in South Carolina was found to exclusively feed on Lepidoptera (Donahue 1998). This is a species that uses its tail and wing membranes to capture prey during feeding maneuvers (Linzey and Brecht 2005).

Seasonal Movements

Little is known about migratory movements of the evening bat. It is thought that northern breeding populations migrate south beginning in mid-October (Watkins 1972) because they are absent there after that time, and because there are reported recoveries of this species from banding studies (Humphrey and Cope 1968). However, in the southern portions of its range, this species may be a winter resident from Texas to as far north as Arkansas (Baker and Ward 1967, Schmidly 1991). In South Carolina, it seems this species is resident because both sexes have been reported year round (Golley 1966). Several evening bats have been found to travel 340 miles (547 km) south of their original summer banding site locations (Humphrey and Cope 1970), and have homing distances ranging from 38 to 95 miles (61 to 153 km) (Cope and Humphrey 1967, Watkins 1969).

Longevity and Survival

Evening bats are thought to have an average life span of two years in the wild, though some individuals have lived for over five years (Watkins 1972).

Threats

The population trends of this species are relatively unknown, though the evening bat is considered state endangered in Indiana where it has best been monitored. This species does appear to be abundant in Missouri and Iowa (Arroyo-Cabrales and Álvarez-Castañeda 2008*b*).

Disturbance or destruction of natural and artificial roost structures are a threat to this species. Evening bats often use buildings and are considered highly sensitive and less tolerant to disturbances by humans compared to big brown bats (*E. fuscus*) (Whitaker and Gummer 1993). There are numerous reports of roosting and nursery colony abandonment due to excessive disturbance, banding and radio telemetry studies, and survey and netting operations (Watkins 1969, Bain 1981, Clem 1992).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides may alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Because evening bats consume crop pests, they may also have an increased risk of contamination from the accumulation of organochlorine pesticides in their body fat. When the fat is metabolized either during migration or hibernation, exposure to these pesticides is increased and can be lethal (Bennett and Monte 2007).

Habitat loss in the form of exclusion and eradication in buildings, removal of old buildings, and conversion of bottomland hardwoods and wetlands threatens evening bats (Amelon and Burhans 2006*c*). Additionally, foraging habitat may be reduced by increased urbanization and loss of riparian habitat. Many of these forms of habitat alterations can also cause increased predation by natural predators. Other potential threats to this species include chemical pollution (Tuttle 1979), waterway siltation (Tuttle 1979), and flooding (Hall 1962).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to evening bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and typical bat boxes, multi-chamber nursery boxes, and structures that mimic large hollow trees may all be reasonable alternatives for evening bats.

Other habitat protection and management recommendations for other South Carolina bat species from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include protecting or managing for longleaf pine stands with a higher overstory, greater canopy density, and greater proportion of basal area composed of conifers, since these habitats are particularly important for nursing colonies in South Carolina (Menzel et al. 2001*a*). Additional measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Other similar measures may include conducting seasonal surveys to identify and monitor roosting and maternity sites, and at buildings being considered for demolition. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Researchers are requested to collect and record bat data, but the SCDNR Heritage Trust does not track this species in its database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Hoary Bat (*Lasiurus cinereus*)

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Description

The hoary bat is the largest bat species in South Carolina, and has the widest range and is considered one of the faster bat species in North America (Barbour and Davis 1969). The pelage is striking compared to most bats, with a rich coloring of yellow, grey-brown, and dark brown with white tips that give this species a distinctive frosted or "hoary" appearance. The high wing loading and high aspect ratio of this species indicates that it is a fast, straight flier (Farney and Fleharty 1969). The migratory speed of this species can exceed 13 miles per hour (21.3 km/h) (Shump and Shump 1982*a*). Unfortunately, the hoary bat is the most prevalent among fatalities reported at wind-energy facilities in North America (Ellison 2012), and compose about half of an estimated 450,000 bat fatalities at wind facilities annually in North America (Cryan 2011).

Identification

The hoary bat weighs 0.9 to 1.1 ounces (25 to 30 grams) and has a wingspan of 8 to 10 inches (21 to 25 cm) (Harvey et al. 2011). This species has thick, dense, soft fur on the uropatagium and body that is highly insulative. The pelage is yellowish-brown to mahogany on the upper side, with white patches on the shoulders and wrists, and a patch of yellow on the throat. The hoary bat has a heavily furred membrane to the tip of its tail. The ears are rounded, thick, and edged black with the outer portion densely furred. The tragus is broad and short. Females tend to be about 4% larger than males (Williams and Findley 1979).

Taxonomy

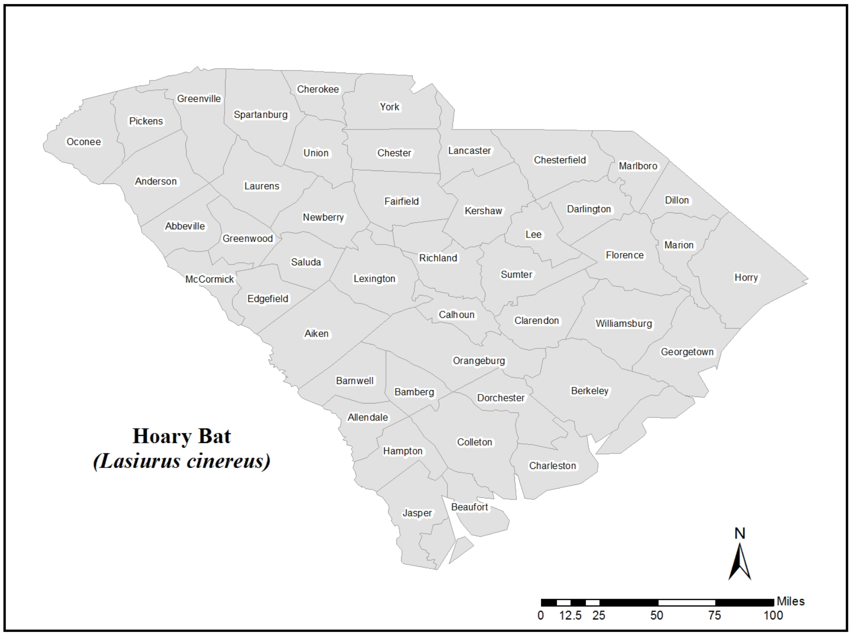
Currently there are three recognized subspecies of the hoary bat (Wilson and Reeder 2005). *Lasiurus cinereus cinereus* is the only subspecies found in South Carolina (Shump and Shump 1982*a*).

Distribution

The hoary bat has the broadest geographic distribution of bat species in the New World, and occurs from southern Canada through most of South America, including most of the US (except southern Florida) and Hawaii. This species winters in southern California, the southeastern US, Mexico, and Guatemala (Shump and Shump 1982*a*). In South Carolina, this species has a more extensive distribution than any other bat, and is found statewide in all four physiographic provinces (M. A. Menzel et al. 2003). However, hoary bats are probably rare in the state during summer due to their migratory patterns.

Population Status

This hoary bat is less common in the eastern US and northern Rockies than it is in the prairie states and northwestern US (Shump and Shump 1982*a*). This species has a rounded rank of Globally Vulnerable (G3G4), Nationally Secure (N5), and Subnationally unranked (SNR) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Gonzalez et al. 2008).



However, no population trend data exists for the hoary bat (NatureServe 2017), and it is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

General Habitat

Due to the extensive range of the hoary bat, this species is found in an extremely wide variety of habitats. In the western US these habitats include the arid deserts and ponderosa pine forests, and in the East, pine-hardwood forests (Tuttle 1995). Additionally, they are seldom found in urban settings, and are most abundant in coniferous forests in the Pacific Northwest and deciduous forests of the plains states in the US (Tuttle 1995). The wide elevation range hoary bats are found in varies from sea level in the Pacific Northwest (Nagorsen and Brigham 1993) to 10,170 feet (3,100 m) in Colorado (Jung et al. 1999).

Roosts and Roosting Behavior

Hoary bats have been found to roost solitarily in tree foliage and tree cavities at the edge of clearings (Constantine 1966). Day roosts used by this species are almost exclusively in the foliage of trees (Shump and Shump 1982*a*, Willis and Brigham 2005). Shump and Shump (1982) reported roosts in trees such as elm (*Ulmus* species), black cherry (*Prunus serotina*), plum (*Prunus* species), box elder (*Acer negundo*), and osage orange trees (*Maclura pomifera*) at about 10 to 16 feet (3 to 5 m) above the ground. They have also been found under a driftwood plank (Connor 1971), and in a gray squirrel nest (Neill 1952).

During summer, hoary bats generally segregate by sex, with males tending to occur in mountainous regions in western North America and the females in eastern regions (Shump and Shump 1982*a*). In Iowa, roosts with an open space below and dense shade and cover above and to the sides were selected (Constantine 1966). In the same study, roosts were mainly found in trees on the edges of forests or fencerows next to crops distant from human populations, and roosted on the side of the tree facing the lower, crop area. However, in Wyoming a roost had higher odds of being chosen with increasing tree height and percent canopy cover at the tree, and decreasing distance to the nearest water and habitat edge (Gruver 2002). In central Ontario, Jung et al. (1999) reported that late successional forests were often occupied by hoary bats, and hypothesized that they used these areas because improved foraging opportunities may be available in old-growth forest with open canopies.

Reproductive females generally roost solitarily with young in tree foliage, and may choose a roost site based on microclimate factors. In Saskatchewan, Canada, roost sites chosen by reproductive females in mature white spruce (*Picea glauca*) were found at the same height as the surrounding forest and on the southeast side of trees, where protection from westerly winds and increased sun exposure resulted in significant energy savings (Willis and Brigham 2005). A female and her young may change roosts often (Veilleux et al. 2009), or use the same roost site for over two weeks (Nagorsen and Brigham 1993, Willis and Brigham 2005).

In fall and winter in California, there appears to be altitudinal separation between the sexes, with males occurring at higher elevations than females (Vaughan and Krutzsch 1954). During winter hoary bats are known to roost in tree foliage, Spanish moss, tree cavities, and squirrel nests (Neill 1952, Cowan and Guiguet 1965, Constantine 1966), but not typically in caves (Myers 1960). In South Carolina, very little is known about night roosts, migration roosts, summer roosts, or winter roosts of hoary bats.

Reproduction

Mating probably occurs in flight during fall migration or on the wintering ground, and sperm is stored in the female's uterus until spring when fertilization takes place (Shump and Shump 1982*a*). Between one to 4, or an average of 2, pups are usually born from mid-May to early July (Bogan 1972, Shump and Shump 1982). Gestation lasts 90 days, young begin to fly by 33 days, and are weaned at seven weeks (Shump and Shump 1982*a*, Whitaker and Hamilton 1998, Koehler and Barclay 2000). Females carry young during flight until they are six to seven days old (Bogan 1972). Postnatal growth is relatively slow, which may be a trait of migrant bats to be able to forage all year (Koehler and Barclay 2000). Sexual maturity of males and females is usually obtained by their first fall (Cryan et al. 2012). Generally young are born and reared in the northeastern, midwestern, and prairie states in the US, and a few as far south as Arkansas, Louisiana, and Tennessee (NatureServe 2017).

Food Habits and Foraging

Foraging by hoary bats does not begin until later in the evening, after many other bat species have already left their roosts (Barbour and Davis 1969). Hoary bats forage all night, and activity tends to peak during the middle of the night (Shump and Shump 1982*a*, Barclay 1985). This species was most active one hour and 40 minutes past sundown in New Mexico (Jones 1965), but most active four to five hours after sunset in Iowa (Kunz 1971). However, the time of emergence and length of foraging bouts for adult females depends on their reproductive stage and number of pups, and ultimately foraging time gradually increases until young fledge (Barclay 1989). Hoary bats may also forage on warm winter days, emerging in the late afternoon (Barclay 1989, Whitaker and Hamilton 1998). There is little data available for distances hoary bats travel from roost sites to foraging sites, and may depend on local factors such as prey availability and abundance. Foraging areas may be located over a mile (1.6 km) away from diurnal roosts (NatureServe 2017), and could include woodland, riparian, and wetland habitats in open areas within the forest, above the forest canopy, and over lakes and streams (Shump and Shump 1982*a*, Barclay 1985, Nagorsen and Brigham 1993). In New Mexico, migrating females foraged along streams below the canopy (Valdez and Cryan 2009). In Manitoba, this species foraged in the lee of a forested ridge surrounded by wet meadows, marshes, and bays where there was less wind (Barclay 1985). Sometimes foraging territories are established (Barclay 1984), and they may forage at a wide range of air temperatures, from 32°F to 72°F (0°C to 22°C) (Jones 1965). In South Carolina, the activity of hoary bats has been recorded widely around Lake Jocassee and Lake

Keowee, in April, July and October at 29 of the 31 sites surveyed (Webster 2013).

Hoary bats are foraging specialists as they feed on relatively few orders of insects compared to other bats, and seems to prefer Lepidoptera (Ross 1967, Black 1972). In New Mexico during spring migration, this species mainly fed on moths along streams until late spring when the focus on moths appeared to decline, potentially due to differential prey selection and/or seasonal prey abundance (Valdez and Cryan 2009). However, this species is also known to consume Coleoptera, Diptera, Orthoptera, Isoptera, Odonata and Hymenoptera, which more specifically includes grasshoppers, dragonflies, and wasps (Ross 1967, Whitaker 1972, Black 1974, Whitaker et al. 1977, Rolseth et al. 1994).

In South Carolina, the foraging habits of hoary bats are not well understood. Three hoary bats studied by Menzel et al. (2003), were recorded on 5.2% of all survey locations at the Savannah River Site. Of those recorded locations, 18.8% were in lake and pond habitat, 7.6% in bottomland hardwoods, 6.8% in grass-brush habitat, 5.0% in loblolly-slash habitat, and 1.4% in longleaf habitat. No records were found in upland hardwood or pine-hardwood habitats. Though activity was low throughout the study site, the highest concentration of activity was in bottomland hardwoods greater than 60 years old.

Seasonal Movements

The hoary bat is highly migratory, and is thought to migrate to southern California, the southeastern US, Mexico and Guatemala for winter (Shump and Shump 1982*a*). However, some hoary bats may remain in northern states and hibernate as they have been found in December and January in Michigan, New York, Connecticut, and Indiana, as well as other northeastern and northwestern states (Whitaker et al. 1980, Shump and Shump 1982*a*, Cryan 2003). Migration during spring probably occurs from April to June (Koehler and Barclay 2000, Cryan 2003, Valdez and Cryan 2009). Female hoary bats generally leave about one month earlier than males, and tend to migrate further than males from wintering grounds in California and Mexico when returning north in the early spring (Cryan 2003, Valdez and Cryan 2009). Migration during fall probably occurs between August and October (Nagorsen and Brigham 1993, Koehler and Barclay 2000, Cryan 2003). The migration patterns of the hoary bat differ depending on the season; fall migration is composed of larger, more organized groups than spring migration (Cryan 2003, Shump and Shump 1982). However, migration routes in both seasons are not well understood. In South Carolina, most individuals of this species probably migrate north in spring and back again in fall or winter. However, there is evidence that some hoary bats are found in the state in the summer (M. A. Menzel et al. 2003).

Longevity and Survival

The hoary bat is thought to live up to six or seven years (Tuttle 1995).

Threats

Wind turbine facilities are the biggest major threat to this species. Hoary bats fatalities are the most prevalent fatalities documented at wind-energy facilities in late summer and early fall (Ellison 2012), and compose about half of an estimated 450,000 bat fatalities at wind facilities annually in North America (Cryan 2011). Because the hoary bat is one of three migratory tree bats that compose the majority of wind turbine fatalities, it has been suggested that seasonality and migration patterns make them more vulnerable to collisions (Cryan 2011). For example, ridge tops may be a major topographical feature used by bats during migration, and facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Additionally, deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981).

Timber harvest of larger trees, and jays in suburban areas may be potential threats to hoary bats (Bolster 2005). Habitat and roost site loss due to development and removal of palm fronds are other potential threats for this species (Bunch et al. 2015*c*). The harvesting of Spanish moss may still be a threat in some areas, but the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). Also, natural causes such as hurricanes may also create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticides on forested public lands may cause mortality to both this species and the insects they prey upon (Bolster 2005). Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Conservation Measures

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to hoary bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); maintain hedgerow habitats along crop borders; retain large trees in urban areas, and Spanish moss and old palm fronds on public lands; and timber management in the Piedmont region that includes pine thinning or controlled burns may benefit this species by creating more open forest areas. Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible, and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to better understand general habitat requirements, population status, summer and winter roost sites, winter habitat, migration information, and behavior of hoary bats; determine the extent and seasonality of off-shore commuting and foraging to assess vulnerability of hoary bats to off-shore wind development; and determine the vulnerability of hoary bats, especially during fall migration, to coastal wind energy development. The SCDNR Heritage Trust tracks high priority species including the hoary bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; and discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees.

Little Brown Bat (*Myotis lucifugus*)

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Description

Though it is one of the most common bats throughout most of the northern US and Canada, in the southern part of its range the little brown bat is scarce or only common locally (Harvey et al. 2011). Aided by its high maneuverability and a fast rate of mastication, this species is well adapted to rapidly consuming swarms of small insects (Kallen and Gans 1972, Fenton and Bell 1979), and can eat 150 mosquitoes in 15 minutes (Fenton 1983, Tuttle 1988). The longest life span of this species has been recorded at an impressive 30 years (Keen and Hitchcock 1980). WNS has greatly impacted populations of little brown bats in its northern range and threatens to push some populations to near extinction (Frick et al. 2010*a*).

Identification

The little brown bat is small to medium sized weighing 0.2 to 0.5 ounces (7 to 14 gr), and has a wingspan of 9 to 11 inches (22 to 27 cm) (Harvey et al. 2011). Its pelage is dark brown to cinnamon-buff with long glossy tips on the dorsum, and pale gray to buffy below. The ears and membranes of the wing and tail are dark brown to black. The ears are narrow and pointed, and the medium sized tragus is blunt. When the ears are gently pressed forward, they reach only to the nostrils. The calcar is not keeled, and the hind foot is relatively large. Females tend to be slightly larger than males in weight (especially during winter) and head, body, and forearm lengths (Fenton 1970, Williams and Findley 1979). This small brown bat resembles the northern long-eared bat (*Myotis septentrionalis*), but misidentification is avoided by the identification of the long, pointed tragus and ears that extend well beyond the nose in the northern long-eared bat (Fenton and Barclay 1980). Additionally, the hairs on the feet of extend beyond the nail in the little brown bat but not in the northern long-eared bat.

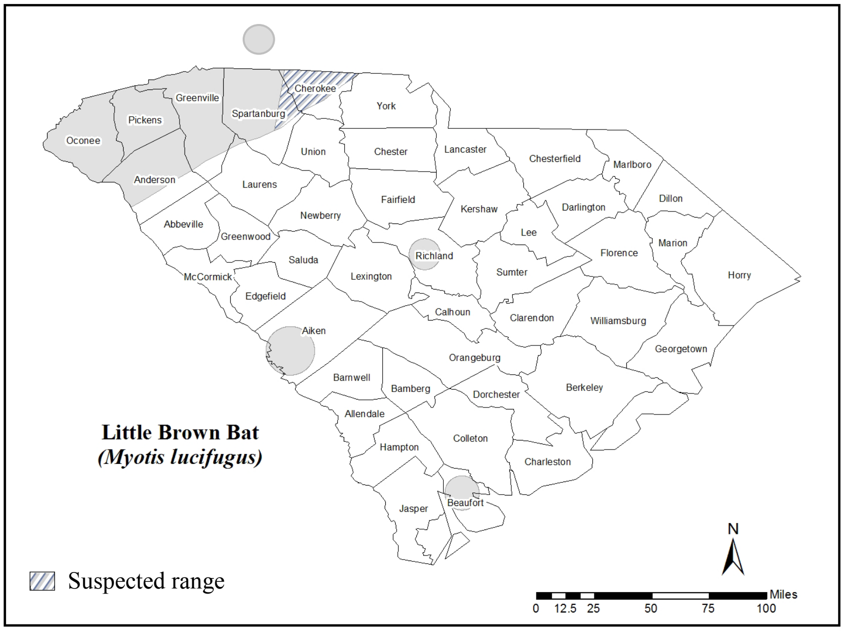
Taxonomy

Currently there are five recognized subspecies of the little brown bat (Wilson and Reeder 2005). *Myotis lucifugus lucifugus* is the only subspecies found in South Carolina (Fenton and Barclay 1980).

Distribution

Little brown bats range from central Alaska and southern Canada into the southeastern and southwestern US, and are widely distributed (Harvey et al. 2011). The southern limit of this species is in northern portions of South Carolina, Georgia, Alabama, and Mississippi (Fenton and Barclay 1980). In South Carolina in summer, little brown bats are found primarily in the Blue Ridge mountains, though there have also been a few confirmed reports in the Piedmont, Sandhills and lower Coastal Plain regions (Davis and Rippy 1968). However, it is unknown where most of South Carolina's summer populations overwinter (Bunch et al. 2015*b*).

Population Status



This species is ranked as Globally Vulnerable (G3), Nationally Vulnerable (N3), and Subnationally Vulnerable (S3?) (NatureServe 2017). However, it is currently ranked as Subnationally Critically Imperiled (S1S2) by the SCDNR Heritage Trust (see Table 2). Yet it is also currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*c*). In South Carolina, the little brown bat is considered rare to locally common in scattered colonies, and is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due in part to severe WNS-related mortality.

General Habitat

Little brown bats are habitat generalists found in a wide variety of ecosystems, likely using most cover types available to them (Barbour and Davis 1969, Fenton and Barclay 1980). However, lakes and streams seem to play a significant factor in habitat use, as much of the foraging activity of this species is associated with aquatic habitats (Fenton and Bell 1979). Little is known about the habitat use and home range of this species in South Carolina.

Roosts and Roosting Behavior

During summer, adult males and immature females are found in day roosts alone or in small groups away from nurseries (Fenton and Barclay 1980). A variety of roosts are used, including tree cavities, under rocks on hillsides, behind sheets of tarpaper, within log piles, and occasionally in caves in late summer and fall (Fenton and Barclay 1980). Little brown bats often use roosts that provide external heat on southwestern exposures for arousal from daily torpor (Fenton 1970).

Reproductive females choose nursery sites with a relatively high ambient temperature, and are usually located in buildings or hollow trees (Davis and Hitchcock 1965, Youngman 1975, Schowalter et al. 1979). The size of maternity colonies range from around 12 to greater than 1,0000 individuals (van Zyll de Jong 1985, Nagorsen and Brigham 1993). Taller, larger diameter trees in older forest habitat are commonly selected by tree-roosting reproductive females (Kalcounis and Hecker 1996, Crampton and Barclay 1998). Tree-roosting colonies are also known to move frequently between roosts (Crampton and Barclay 1998). In South Carolina, not much is known about the roosting habits of this species. However, summer roosts and maternity colonies have been found in the state in buildings and picnic shelters, such as those at the SCDNR Fish Hatchery in Oconee County (Bunch et al. 2015*b*).

Nursery colonies disperse by midsummer, and swarming activity takes place at hibernacula from around August through October (Fenton and Barclay 1980). It is during this time that different populations of little brown bats mix and are thought to initiate mating relationships, which may ultimately result in the prevention of genetic isolation (Fenton 1969, Carmody et al. 1971). To conserve energy, little brown bats regularly enter torpor. During summer torpor they wake from stimulation of external factors, but while hibernating in winter this species spontaneously arouses from torpor (Menaker 1961).

During winter, both sexes of this species usually hibernate together in caves or mines with high levels of humidity (70-95%) and temperatures above freezing (33.8 to 41°F; 1 to 5°C) (Fenton 1970, Humphrey and Cope 1976, Nagorsen and Brigham 1993). Mines are used more than scattered caves in Ontario, and males comprise over 75% of the population in mines and 65% in caves (Fenton 1970). Depending on torpor arousal frequency and local weather conditions, hibernation lasts from early September through mid-May in the northern portions of its range, or from around November to mid-March in the southern portions (Fenton and Barclay 1980). Little brown bats lose about 25% of their fall weight during hibernation (Fenton 1970). Little brown bats can find roost sites using echolocation calls emitted by others from mating sites within hibernacula (Thomas et al. 1979, Fenton and Barclay 1980). In South Carolina, one hibernacula has been found in a single cave in Pickens County (Bunch et al. 2015*b*). However, not much is known about overwintering habits of the population of little brown bats in the state.
Night roosts are generally located in confined spaces into which groups of bats congregate, and are often located in different places in the same buildings used as day roosts (Barclay 1982). Though the function of night roosts remain unclear, it seems likely that increased roost temperatures are energetically beneficial and may speed up the digestive process (Buchler 1975, Fenton and Barclay 1980).

Reproduction
Mating usually occurs one month after the fall onset of swarming, and most females store sperm through the winter months (Thomas et al. 1979). Mating may also occur after females leave hibernation in the spring, happening earlier in the year in the more southerly portions of this species range (Fenton and Barclay 1980). A single pup is born in the spring, which occurs earlier in the year at lower elevations than at higher elevations (Nagorsen and Brigham 1993). Pups are born anywhere from mid-May to August depending on the location (Fenton et al. 1980, Perlmeter 1996). In Kentucky they are born from mid-May to late June (Humphrey and Cope 1976).

Gestation lasts 50 to 60 days, and young begin to fly and are weaned around week three (Wimsatt 1944, Schowalter et al. 1979, Fenton and Barclay 1980). Sexual maturity is reached within the first year in females but most don't breed until the second year, and males reach sexual maturity in their second year (Gustafson and Shemesh 1976, Thomas et al. 1979, Herd and Fenton 1983).

Food Habits and Foraging
Little brown bats emerge from their roosts shortly after dusk to feed, with the most activity occurring two to three hours after sunset (Herd and Fenton 1983, Nagorsen and Brigham 1993). With low wing loading, a low aspect ratio, and rounded wing tips, this species is highly maneuverable, and travels around 0.6 to 9 miles (1 to 14 km) from their day roosts to foraging areas (Henry et al. 2002). Little brown bats vary their hunting patterns over an evening. Initially feeding

along margins of lakes and streams and in and out of vegetation 7 to 16 feet (2 to 5 m) above the ground, they later forage 3 to 7 feet (1 to 2 m) over the surface of water in groups (Fenton and Bell 1979). Little brown bats have been found to be most closely associated with riparian zones along streams greater than third-order in the central Appalachians (Ford et al. 2005). Not much is known about the home range or habitat use of this species in South Carolina. However, the activity of little brown bats has been recorded in April, July and October at Keowee Toxaway State Park at Cedar Creek, Lake Jocassee, Stamp Creek marsh, Fall Creek Island, Devils Fork/Howard Creek, the shoreline on Lake Jocassee at Double Spring Mountain west, Thompson River, and the Upper Horsepasture River (Webster 2013).

Aided by their maneuverability, a rapid rate of mastication at seven jaw cycles per second, and relatively quick passage of food through the digestive tract, little brown bats are well adapted to rapidly consuming swarms of small insects (Kallen and Gans 1972, Buchler 1975, Fenton and Bell 1979). This species consumes a wide variety of prey, and selection may be based on size or species depending on the situation (Buchler 1976). In British Columbia, this species fed on Lepidoptera, medium-sized to large Diptera, Neuroptera, and Hymenoptera (Burles et al. 2008). However, little brown bats are known to prey heavily on aquatic insects such as midges, and generally tend to consume insects between 0.11 to 0.39 inches (3 to 10 mm) (Belwood and Fenton 1976, Anthony and Kunz 1977). One-hundred and fifty mosquitoes can be consumed in 15 minutes by little brown bats (Fenton 1983, Tuttle 1988). Little brown bats show a greater variation in diet in the northern portions of its range than the southern portions, potentially due to having less foraging time and a more patchy distribution of prey in the North (Belwood and Fenton 1976, Anthony and Kunz 1977). In South Carolina, however, the diet of the little brown bat is unknown.

Seasonal Movements

Between hibernacula and summer roosts, female little brown bats migrate several hundred miles, but not much is known about the seasonal movements of males (Davis and Hitchcock 1965, Fenton 1970, Humphrey and Cope 1976). In the western US, little brown bats are thought to hibernate near their summer range, but in the northeast they may migrate hundreds of miles (Schmidly 1991). It is unknown where most of South Carolina's summer populations spend the winter (Bunch et al. 2015*b*).

Longevity and Survival

The longest lifespan of the little brown bat was recorded at 30 years in southeastern Ontario (Keen and Hitchcock 1980), but more commonly live six to seven years old and are often reported at over 10 years old (Humphrey and Cope 1976, Arroyo-Cabrales and Álvarez-Castañeda 2008*c*)(Humphrey and Cope 1976). The mean life expectancy calculated using band recovery data suggest 1.55 years for males and 1.17 to 2.15 years for females, with the first winter of life having the highest mortalities (Humphrey and Cope 1976). The mean annual survival rate calculated by Keen and Hitchcock (1980) was 0.82 for males and 0.71 for females. Survival rates are higher in adults at 63-90% than in juveniles at 23-46% (Frick et al. 2010*b*).

Threats

The primary threat to this species is WNS, which has killed at least one million little brown bats from 2006 to 2010 and caused severe declines in abundance in the eastern portion of its range (Frick et al. 2010*a*, Kunz and Reichard 2010). Annual population decrease for bats found at infected hibernacula ranges from 30 to 99% (Frick et al. 2010*a*). The core region where much of the global population of little brown bats occur is now infected with WNS, and threatens to push these core northeastern populations to extinction by 2026 (Frick et al. 2010*a*, Kunz and Reichard 2010).

In many parts of its range, populations of the little brown bat have also declined drastically in part due to pesticides, the loss of roost sites in snags due to deforestation, control measures in nursery colonies, collecting bats for experimentation, and disturbance of individuals during hibernation (Fenton and Barclay 1980, Parker et al. 1996). Mass die-offs at hibernacula not related to WNS have been associated with vandalism and natural disasters such as floods (DeBlase et al. 1965, Gould 1970).

Pesticides cause mortality to this species when applied directly for control purposes, or indirectly to their insect prey (Kunz et al. 1977). Bats may also suffer from a delayed affect from high levels of insecticides released from stored fat deposits metabolized during weaning, migration, and at the end of hibernation (Geluso et al. 1976).

Wind energy is another potential threat to little brown bats, though reported fatalities are much lower than for migratory tree bats. In a study by Johnson et al. (2003), little brown bats were one of six bat species killed at a wind power development at Buffalo Ridge, Minnesota. In a review of bat mortality at wind energy developments in the US by Johnson (2005), little brown bats comprised 5.9% of the total fatalities. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Global climate change is a potential threat to little brown bats because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to little brown bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and multi-chamber nursery boxes are a reasonable alternative for little brown bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include locating hibernacula of little brown bats and monitor winter colonies; conducting demographic studies on this species to measure the effects of WNS if it occurs; monitoring the little brown bat maternity colony at the SCDNR Fish Hatchery in Oconee County; conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the little brown bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Northern Long-eared Bat (*Myotis septentrionalis*)

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Description

This medium sized brown bat has short, broad wings well adapted to foraging in clutter (Norberg and Rayner 1987), and is often found in mature forests due to the importance of this habitat for roosting and foraging (Caceres and Pybus 1997). WNS is a substantial threat to northern long-eared bats, as it is linked to mortality of up to 100% in some populations (Blehert et al. 2009). Northern long-eared bats are particularly vulnerable to external threats due to life history traits that make it slow to recover, such as low fecundity (Caceres and Pybus 1997, Caceres and Barclay 2000). In October of 2013 the USFWS proposed a status of Endangered under the ESA for the northern long-eared bat due to threats from WNS. In April of 2015 it was determined this species met the ESA definition of Threatened, and 30 days later the listing became effective with an interim 4(d) rule providing flexibility to specific entities who conduct activities in northern long-eared bat habitat (USFWS 2015*a*). This species was found on the SC Coastal Plain (Beaufort County) in 2016.

Identification

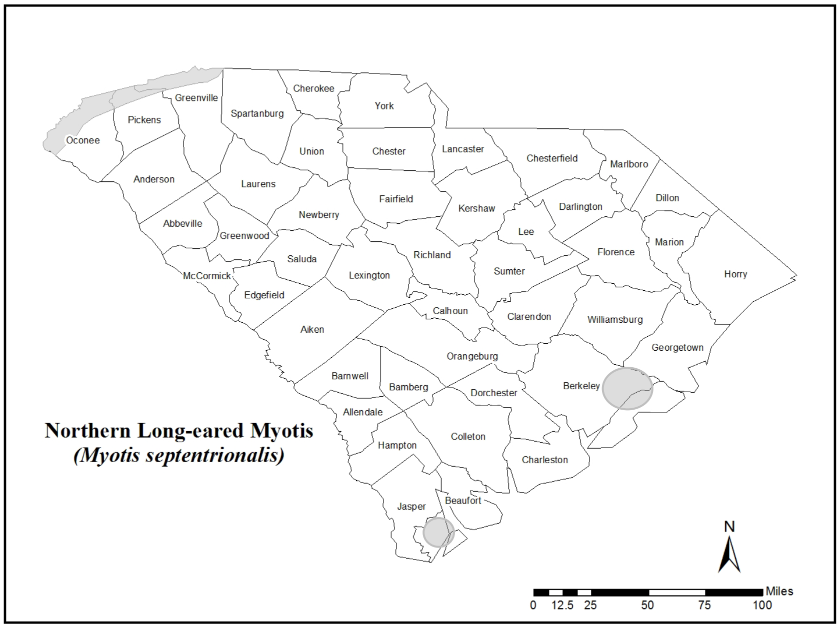
This species weighs 0.2 to 0.3 ounces (6 to 9 gr) and has a wingspan of 9 to 10 inches (23 to 26 cm) (Harvey et al. 2011). Its pelage is light brown to gray brown on the dorsum, and pale grayish brown to pale brown below. The ears and membranes of the wing and tail are slightly darker brown than the dorsal pelage. The ears are narrow and pointed, and the long tragus is pointed. When the ears are gently pressed forward, they reach beyond the tip of the nostrils. The calcar may either be slightly keeled or the keel may appear to be lacking (Trani et al. 2007). Females tend to be heavier than males (Caire et al. 1979, Williams and Findley 1979). The northern long-eared bat resembles other *Myotis* species, but misidentification is avoided by the identification of the long, pointed tragus and ears that extend more than 2 mm beyond the tip of the nose (Menzel et al. 2002*c*). Additionally, this species has a faint black mask, longer rostrum, missing hair around the eyes, and is generally smaller than the little brown bat.

Taxonomy

The northern long-eared bat is considered monotypic (Wilson and Reeder 2005).

Distribution

Northern long-eared bats are widely but patchily distributed across eastern North America ranging from southern Canada and the central and eastern US, northwest to the Dakotas, west through the central states, and south to northern Florida. Historically, this species was more common in the northern portion of the range than the southern and western portions (Amelon and Burhans 2006*a*), and is still relatively uncommon in most of the South (Barbour and Davis 1969,



Sealander and Heidt 1990). In South Carolina, northern long-eared bats used to be found primarily in the Blue Ridge mountains where they had once been considered common. There have also been a few confirmed reports in the Coastal Plain of North Carolina (Grider et al. 2016).Then in November 2016, two individuals were discovered on the Coastal Plain of South Carolina in Beaufort County, and another nine individuals were found breeding in Berkeley and Charleston counites in June and July of 2017. Currently, the USFWS considers the range of the northern long-eared bat to be more extensive than our SC map, as seen in its WNS Buffer Zone map (Figure 6; https://www.fws.gov/midwest/endangered/mammals/nleb/pdf/WNSBufferZone.pdf), and includes the following South Carolina counties: Abbeville, Anderson, Beaufort, Berkeley, Charleston, Cherokee, Colleton, Dorchester, Florence, Georgetown, Greenville, Hampton, Horry, Jasper, Laurens, Marion, Oconee, Pickens, Spartanburg, Union, Willamsburg and York.

Population Status

Common over much of its range, this species has a rounded status of Critically Imperiled both Globally (G1G2), and Nationally (N1N2), and Subnationally Apparently Secure (S4) (NatureServe 2017). However, it is currently ranked as Subnationally Critically Imperiled (S1) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*d*). However, the northern long-eared bat is listed as federally threatened (USFWS 2015*a*). In South Carolina the northern long-eared bat is generally considered rare, is listed as a Highest Priority species in the South Carolina 2015 SWAP, and because of the federal threatened listing is now considered state threatened (SCDNR 2015).

General Habitat

Northern long-eared bats are often found in mature forests due to the importance of this habitat for roosting and foraging (Caceres and Pybus 1997), and may prefer old-growth with intact interior and low edge-to-interior ratios (NatureServe 2017). However, this species is also found in a variety of habitats including mature second-growth eastern deciduous forests, clearcuts, deferment harvests, streams, and road corridors (M. A. Menzel et al. 2003). In South Carolina, sparse vegetation and mature tree stands were found to be the best predictor of foraging habitat use by northern long-eared bats (Loeb and O’Keefe 2006).

Roosts and Roosting Behavior

Northern long-eared bats have been found roosting in tree cavities (Owen et al. 2001, Menzel et al. 2002*d*), under the bark of trees (Mumford and Cope 1964), in buildings (Doutt et al. 1966, Turner 1974), behind shutters (Mumford 1969), storm sewers (Goehring 1954), and in caves, mines, and crevices in rock outcrops (Harvey et al. 1999*a*, *b*). In a Arkansas study, 85% of male and 95% of female roosts were found in snags, most of which had a 10 to 25 cm dbh (Perry and Thill 2007*b*). The wide range of tree species chosen as roost sites across the range of northern long-eared bat shows opportunistic selection at the microhabitat scale when it comes to roost-sites (Foster and Kurta 1999, Cryan et al. 2001). In Illinois, the average roost height for this species was 30 feet (9 m) (Carter and Feldhamer 2005).

During summer, males and non-reproductive females roost separately, either singly or in small groups of less than 10 in trees, buildings, and caves (Turner 1974, Nagorsen and Nash 1984, Nagorsen and Brigham 1993). Males tend to choose roosting sites in live-damaged trees with a relatively small diameter (Lacki and Schwierjohann 2001, Perry and Thill 2007*b*, O'Keefe 2009). Males and non-reproductive females also use night roosts located in caves, mines, and quarry tunnels, which differ from day roost habitats (Jones et al. 1967, Clark et al. 1987). In South Carolina during summer, a northern long-eared bat was tracked to a location under the loose bark of a dead pine near National Forest land in Oconee County (Bunch and Dye 1999*b*). According to the USFWS (2015*b*), potential suitable summer habitat for northern long-eared bats may include live trees and/or snags with a dbh greater than or equal to 3 inches (7.62 cm) that have cavities, crevices, exfoliating bark, and/or cracks, and are within 1,000 feet (305 m) of forested habitat. In addition, wooded corridors and human-made structures should also be considered potential suitable summer habitat. However, summer roosting habits in South Carolina are not well known.

Maternity colonies of 30 to 60 individuals generally roost in trees, tree cavities, under bark, under shingles, and in buildings (Foster and Kurta 1999, Caceres and Barclay 2000, Whitaker and Mumford 2009). In the southern Appalachian Mountains, maternity colonies of 75 were found in northern red oaks with a dbh of > 16.5 inches (42 cm) and approximately 150-200 years old. Regardless of geographic location, warm sites are selected in order to maximize the growth of young (Amelon and Burhans 2006*a*). Studies show females in maternity colonies prefer roosts in tall hardwood trees in early stages of decay (Sasse and Pekins 1996, Caceres 1998), in live trees with less canopy closure (Caceres 1998, O'Keefe 2009), and in large diameter trees (Sasse and Pekins 1996, Foster and Kurta 1999, O'Keefe 2009). However, Owen et al. (2001) found that selected roosts in West Virginia were in taller, smaller diameter trees, surrounded by more live overstory trees and snags, and surrounded by a higher basal area of other snags. Tree colony sites occupied in Canada had more mature, shade-tolerant deciduous tree stands than summer roosts occupied by males in conifer-dominated stands (Broders et al. 2006). Maternity roosts were also found to be associated with upper and mid slopes in Kentucky (Lacki and Schwierjohann 2001). Additionally, females within the colony may frequently switch roost trees, and roost site selection may vary depending on reproductive stage. For example, during lactation females may switch roost trees every two to five days and roost higher in trees located in areas of relatively less canopy cover and tree density compared to pre- and post- lactation stages

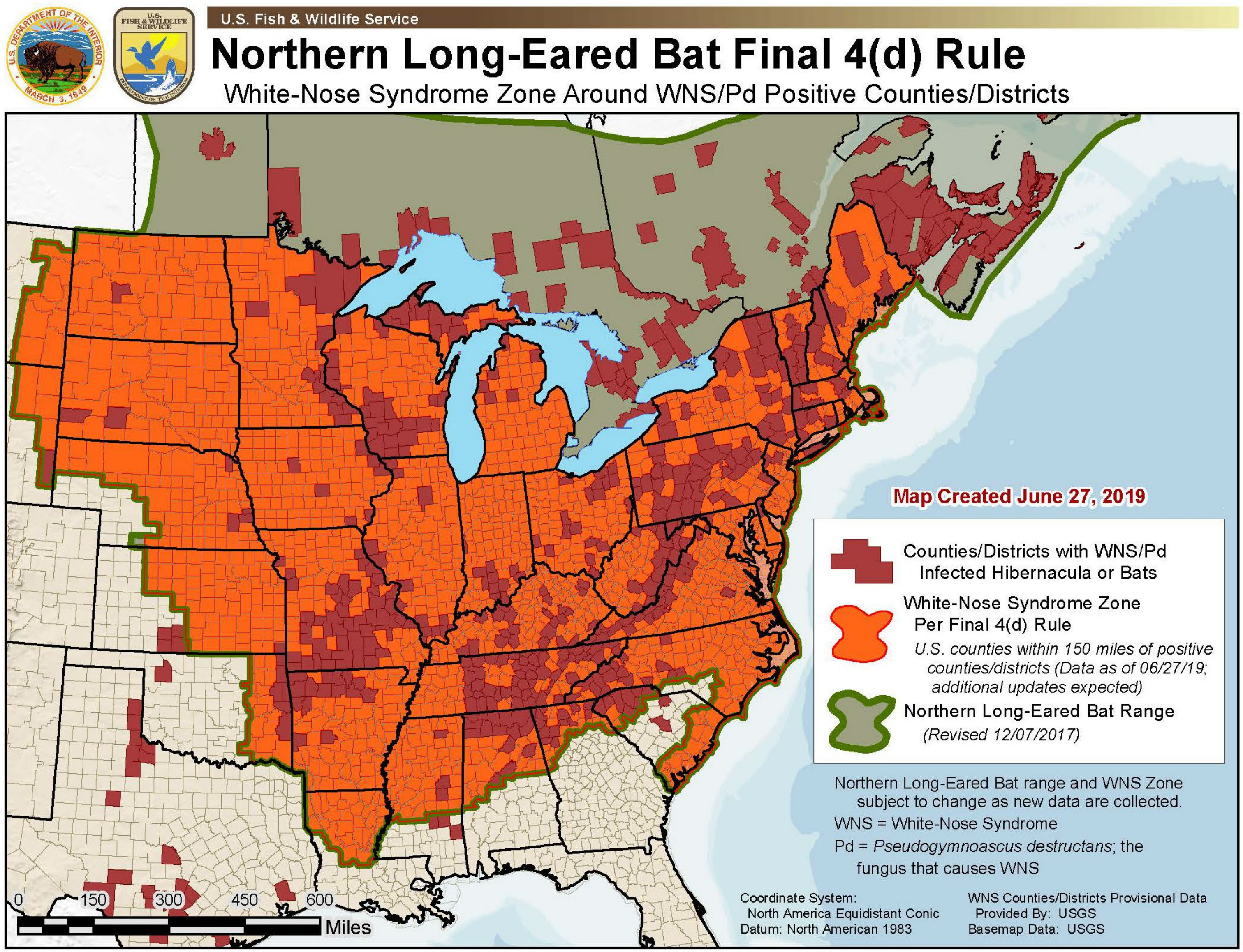


Figure 6: USFWS northern long-eared bat range map with WNS 150-mile buffer zone.*
http://www.fws.gov/midwest/endangered/mammals/nleb/pdf/WNSBufferZone.pdf

(Foster and Kurta 1999, Garroway and Broders 2008). Maternity colony size has been shown to decline as summer progresses, with the largest colonies for pregnant females, medium-sized colonies used by lactating females, and smaller colonies used by post-lactating females (Lacki and Schwierjohann 2001). Females return to their natal sites annually (Arnold 2007). Maternity colony habits in South Carolina are unknown.

During late fall and winter (around October through April), northern long-eared bats hibernate either singly or in small groups rarely exceeding 100 individuals (Amelon and Burhans 2006*a*), though they can include 350 individuals (Hitchcock 1949, Heath et al. 1986). They may be found with large numbers of other species of bats, including the big brown bat, little brown bat, and tricolored bat (Hitchcock 1949, Mills 1971, Caire et al. 1979). This species may hibernate for up to nine months in the northern part of its range (Stones and Frum 1969), and by the end of winter have lost 41 to 45% of the fat stores gained prior to hibernation (Caire et al. 1979, Caceres and Barclay 2000). This species is commonly found in the crevices on walls or ceilings (Caire et al. 1979, Whitaker and Gummer 2001) of hibernacula that include caves, mines, storm sewers, and crevices in rock outcrops (Goehring 1954, Harvey et al. 1999*a*, *b*). Preferred sites have high humidity and consistent low temperatures (Fitch and Shump 1979, Whitaker and Mumford 2009). Northern long-eared bats are known to wake from torpor on warm winter nights, change locations within the hibernacula, or fly outside the hibernacula (Whitaker and Rissler 1992*a*, Whitaker and Mumford 2009). Relatively high fidelity to hibernacula has been recorded in this species. In a study conducted by Griffin (1945), for every bat recaptured elsewhere, 100 bats were observed returning to their cave of origin over subsequent winters. In other studies, 5% of the original banded population (which can be over 90% of recaptured individuals) were subsequently recaptured at the same hibernacula the following fall (Mills 1971, Caire et al. 1979). In South Carolina, northern long-eared bats have been detected at two known hibernacula: 26 individuals were found in a cave in 1995 (which has not been surveyed since), and one individual was found in a tunnel in 2011 (Bunch et al. 1998*a*, Bunch 2011). However, the winter roosting habits for this species are not well known in the state.

Reproduction

Mating begins from late July in the northern portion of this species' range to late August in the southern portion, and completes by September and October (Amelon and Burhans 2006*a*). Sperm is probably stored in the female's uterus until spring when fertilization takes place, though breeding activity may extend into spring (Racey 1982). In northern areas, females leave hibernacula starting in May with peak numbers leaving in late June, and in southern areas females leave hibernacula starting in March with peak numbers leaving in May (Amelon and Burhans 2006*a*). A single pup is usually born between mid-May and mid-June in the southeastern portions of its range, but may be as late as mid-July in the more northern portions (Caceres and Barclay 2000). Gestation lasts 50 to 60 days (Baker 1983), young begin to fly at three weeks (Kunz 1971, Feldhamer et al. 2001), and lactation lasts around 30 days (Ollendorff 2002). Male and female young may mate their first fall, but details are unknown (NatureServe 2017). The reproductive habits of the northern long-eared bat are unknown in South Carolina.

Food Habits and Foraging

Emerging to forage at dusk, the northern long-eared bat has peaks of foraging activity one to two hours after sunset and seven to eight hours after sunset (Barbour and Davis 1969, Kunz 1973). This species is considered a clutter-adapted species and often forages in densely forested areas (Norberg and Rayner 1987). With a rounded wing tip and relatively low aspect ratio of 5.8 and wing loading of 6.8 (Norberg and Rayner 1987), the northern long-eared bat has a relatively slow, maneuverable flight well adapted to a gleaning foraging strategy in canopy gaps and forested areas with open understories where prey is consumed off of foliage while feeding (Amelon and Burhans 2006*a*). Mature, intact forests are an important habitat for roosting and foraging areas in this species (Caceres and Pybus 1997, Patriquin and Barclay 2003, Loeb and O'Keefe 2006, Perry and Thill 2007*b*). However, high post-harvest occupancy of northern long-eared bats in newly cut areas of national forest in North Carolina has been observed (O'Keefe et al. 2013). They may also utilize foraging areas in trees among hillsides and ridges (LaVal et al. 1977); along stream corridors, in adjacent agricultural lands and floodplains and in mature deciduous uplands (Kunz 1973, 1971); over ponds (Cowan and Guiguet 1965, Brack Jr. and Whitaker 2001); and on the ground (Kirkland 1997). Foraging home ranges for females have been reported in West Virginia at an average of 150 acres (61.1 ha) (Menzel et al. 1999*b*). Reproductive females have been shown to travel an average of around 2,000 feet (602 m) from maternity roosts to foraging areas (Sasse and Pekins 1996).

As an opportunistic insectivore, the northern long-eared bats feeds on Araneae, Lepidoptera, Coleoptera, Trichoptera, Diptera, and Plecoptera (Whitaker 1972, Belwood 1979, LaVal and LaVal 1980) with spiders, moth and butterfly larvae composing 12.7% of stomach contents (Brack Jr. and Whitaker 2001). In more than 50% of fecal pellet samples taken from individuals in the central Appalachians, Coleoptera, Lepidoptera, and Neuroptera fragments were found (Griffith and Gates 1985). Though geographic location, season, and individual preference may contribute to a varying diet in this species (Whitaker 1972, Caceres 1998), foraging habits for this species are unknown in South Carolina.

Seasonal Movements

The winter and summer ranges of northern long-eared bats have been reported to be the same, and are thus not considered a migratory species (Barbour and Davis 1969). However some populations may move seasonally, traveling up to 35 miles (56 km) between hibernacula and summer habitat (Caire et al. 1979). Movements between February and April have also been reported, with an individual traveling 60 miles (97 km) between caves (Griffin 1940).

Longevity and Survival

The longest life span recorded of a northern long-eared bat was 18.5 years old (Hall et al. 1957).

Threats

Northern long-eared bats are particularly vulnerable to external threats due to life history traits that make it slow to recover, such as low fecundity (Caceres and Pybus 1997, Caceres and Barclay 2000).

WNS is a substantial threat to northern long-eared bats, as it is linked to mortality of up to 100% in some populations (Blehert et al. 2009). Mortality has occurred across portions of its range (Gargas et al. 2009), and threatens to impact significant portions in the near future. According to Frick et al. (2015), there has been a loss of 69% of the northern long-eared bat's former hibernacula.

A ten-fold decrease in the numbers of bats in North American hibernacula has been attributed to WNS, and significant local extinctions in many species have resulted, including up to 69% of former hibernacula of the now federally threatened northern long-eared bat (Frick et al. 2015).

According to Alves et al. (2014), an expected relative population reduction for this species is estimated to be 31.3% in an intermediate population-reduction scenario, compared to a pessimistic scenario of 42.4%, and an optimistic scenario of 12.9% population reduction. In the event of pessimistic and intermediate scenarios, this species will be considered Vulnerable.

Habitat fragmentation through various activities may reduce occupancy of this species in forested habitat due to increased edge habitat (Yates and Muzika 2006).

Deforestation is a threat to this species as it causes direct loss of roosting and foraging habitats and changes insect abundance and distribution (Hayes and Loeb 2007). Because mature forest stands are important habitat for northern long-eared bats (Caceres and Pybus 1997), even-age timber management practices could have an adverse effect on this species. Additionally, oil, gas, and mineral development activities may also negatively impact northern long-eared bats through alternation or removal of mature forested habitats (USFWS 2011).

Wind energy development threatens this species through some mortality from the facilities themselves (Kerns and Kerlinger 2004, Johnson 2005), as well as through potential clearing of mature forests for turbines and road construction. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Disturbance and vandalism of hibernacula by human activities poses a great threat to this species (Tuttle 1979, Thomas et al. 1990, Caceres and Pybus 1997). Along with disturbance during maternity periods, these threats are a significant factor in the widespread decline of species dependent on caves and mines (Amelon and Burhans 2006*a*). The energy demands made on hibernating northern long-eared bats may be increased from repeated arousal due to human disturbance, forcing northern long-eared bats to burn critical fat reserves (Caceres and Pybus 1997). This loss of energy stores may affect overwinter viability, and in addition, may cause lower reproductive rates since females may become significantly lighter in weight during the reproductive period (Reichard and Kunz 2009). Destruction of hibernacula is the main factor in population declines of bat species dependent on caves and mines (Humphrey 1978, Sheffield and Chapman 1992). Mine closures cause direct mortality to this species if they occur during hibernation. Closing mines during non-hibernating periods may force northern long-eared bats to burn critical fat reserves while searching for new hibernacula (USFWS 2011).

Another threat to northern long-eared bats is the inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species. These protections are meant to prevent trade or possession of state-listed species, but do not protect against habitat destruction (USFWS 2011).

Global climate change is also a potential threat to this species because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). Northern long-eared bats do not typically use buildings, but to minimize negative impacts to this species when they do, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures in the event of a disturbance, and multi-chamber nursery boxes may work for northern long-eared bat colonies (though evidence is currently lacking).

Since roost sites for this species at various life stages have been found in a wide range of live trees and snags in all size classes, best forest management practices would allow for diversity in tree species, snag conditions, and size classes (Lacki and Schwierjohann 2001, Menzel et al. 2002*d*, Ford et al. 2006*b*). Mature forest stands are important roosting and foraging habitat for northern long-eared bats (Caceres and Pybus 1997), so avoiding even-age timber management practices and keeping contiguous tracts of mature forest would provide the best habitat for this species. Maintaining closed forest conditions will also benefit northern long-eared bats since they often forage in closed upland forest and intact forest stands (Owen et al. 2003, Ford et al. 2005). Protecting or managing for potential summer roost habitat such as live trees and/or snags with a dbh greater than or equal to 3 inches (7.62 cm) that have cavities, crevices, exfoliating bark, and/or cracks and are within 1,000 feet (305 m) of forested habitat (USFWS 2015*b*) may benefit this species. Managing for wooded corridors and conducting surveys for this species in human-made structures could also be beneficial as they are considered suitable summer roosting habitat as well (USFWS 2015*b*).

Recommendations from NatureServe (2015) state that caves and mines that serve as hibernacula should be protected from October through April, and include a buffer zone to protect from disturbances such as logging that might change water and air flow, temperature, and humidity. Additionally, maternity colony roosts and surrounding habitat should be protected during late spring and early summer, with adjacent foraging areas protected from deforestation.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to maintain intact, mature forest stands; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include locating hibernacula for this species in the state; conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the northern long-eared bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Northern Yellow Bat (*Lasiurus intermedius*)

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Description

The northern yellow bat is the second largest bat in South Carolina, but one of the least known mammalian species in the state. Spanish moss (*Tillandsia usneoides*) is a preferred roosting site of northern yellow bats, and the distribution of this species is therefore closely associated with the range of Spanish moss (Barbour and Davis 1969). Northern yellow bats differ from other tree roosting species such as eastern red bats in that only the dorsal surface of the uropatagium is furred, there are no white patches on the shoulders or wrists, and the ears are more pointed. This species is also more social and may form colonies during the nursing season (Reid 1997). Very little is known about northern yellow bats compared to other North American bat species, and it is the least understood mammalian species in South Carolina (Bunch et al. 2015*c*).

Identification

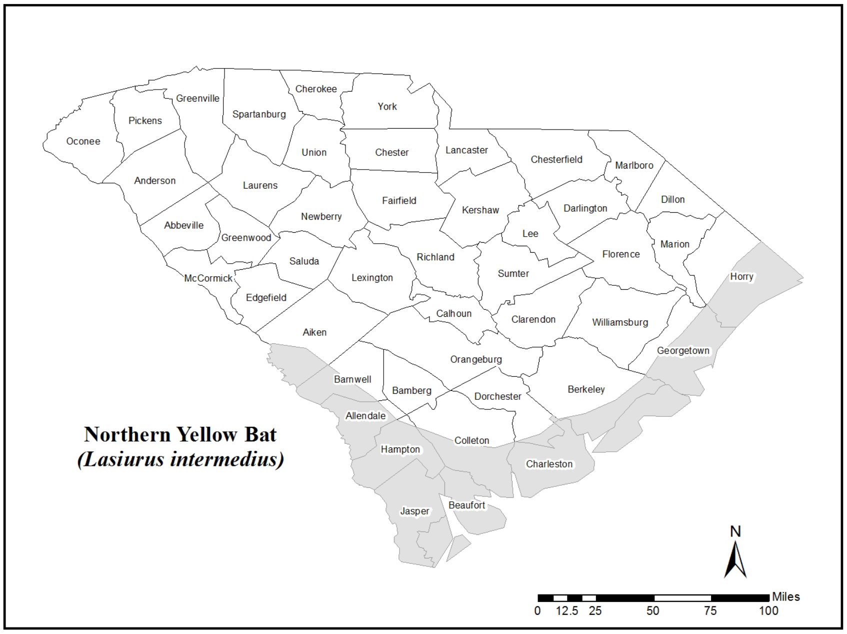
The northern yellow bat weighs 0.5 to 1.1 ounces (14 to 31 gr) and has a wingspan of 14 to 15 inches (35 to 39 cm) (Harvey et al. 2011). The pelage is long and silky, and varies from yellow-orange to yellow-brown and is faintly washed with brown or gray above, and light yellow below. The dorsal surface of the uropatagium is furred on the basal third or half, unlike other *Lasiurus* species whose uropatagium is also furred on the ventral surface. Females have four mammae and tend to be larger than males. The wing membranes are brownish, and the calcar is slightly keeled. The ears are relatively short and rounded, though they are considered more pointed than other tree roosting species (Webster et al. 1980).

Taxonomy

Currently there are two recognized subspecies (Wilson and Reeder 2005) of the northern yellow bat, though this has been debated in the past (Whitaker and Hamilton 1998). However, only *Lasiurus intermedius floridanus* has been confirmed in South Carolina.

Distribution

The distribution of the northern yellow bat is poorly known, but is thought to be restricted to the coastal areas of the southeastern US and southward into Central America (Webster et al. 1980). In the US this species has been found as far north as coastal New Jersey (Koopman 1965), though it was presumed to be an accidental occurrence, and in Virginia. The range extends south to the Coastal Plain of Georgia and Alabama and into Florida, and west along the coast to south-central Texas and southward into eastern Mexico (Webster et al. 1980). In South Carolina, this species is found in the Lower Coastal Plain and into the Upper Coastal Plain along the Savannah River (Bunch et al. 2015*c*).



Population Status
Density and population estimates for northern yellow bats are unknown across its range, and are not available for South Carolina. This species is generally considered to be rare except in central Florida where it is the most abundant bat (Humphrey 1992), this species is not assessed adequately elsewhere due to lack of information. Its rank is Globally Secure (G5), Nationally Apparently Secure (N4), and is Subnationally Unranked (SNR) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Miller and Rodriguez 2008). This species is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due in part to the lack of information about northern yellow bats and the severe WNS-related mortality occurring in other bat species.

General Habitat
Northern yellow bats are generally associated with Spanish moss or palm trees in coastal habitats of the southeastern US, and typically found in wooded areas near permanent water (Webster et al. 1980). They are also found in lowland prairie, marsh, and wooded habitats of Texas (Schmidly 1991), as well as dry upland sites in the central peninsula of Florida and throughout the state (Sherman 1944, Jennings 1958, Humphrey 1992).

Roosts and Roosting Behavior
During summer, northern yellow bats usually roost alone and have been found in Spanish moss in live oaks (*Quercus virginiana*) in Georgia and Florida (Jennings 1958, Menzel et al. 1995, Coleman et al. 2012), in pine-oak woodlands in Florida and Mexico (Sherman 1944, Jones 1964, Carter and Jones 1978), in the grooves of palm trees in Texas (Davis 1974), and on the stems of hardwoods in Virginia (Rageot 1955). Usually this species doesn't use buildings, but Koopman (1965) reported one specimen found in a garage. Though a solitary rooster, individuals of this species are known to aggregate into the same tree (Jennings 1958). No studies have been conducted on the summer roosting habits of northern yellow bats in South Carolina.

There has been evidence that maternity roosts form during the nursing season. In July in Catamaco, Veracruz, a communal roost of 45 individuals with lactating females and smaller individuals with unworn teeth (potentially young of the year) were reported flying out from under corn stalks hanging from the side of an old tobacco-curing shed (Baker and Dickerman 1956). From June through August, adult females and young have been found in feeding and roosting groups (Barbour and Davis 1969, Davis 1974).
The winter roosting habits of the northern yellow bat are not well known, and there

haven't been any studies investigating those habits in South Carolina. There have been records of northern yellow bats in January in South Carolina (Golley 1966), suggesting they may overwinter in the state. Since this species may become torpid when exposed to cold temperatures (Rageot 1955), it is possible that the northern yellow bat might hibernate during winter in the northern portions of its range in Virginia and North Carolina where they may be considered a resident (Lee et al. 1982, Linzey 1998). However, northern yellow bats are also known to forage on warm nights elsewhere during this time (Jennings 1958). Sexual segregation occurs during winter, and in Florida, males may congregate during this time (Barbour and Davis 1969).

Reproduction

Reproduction and the extent of the mating season are not completely understood for the northern yellow bat. It is thought that mating occurs in the fall and winter, and sperm is stored in the female's uterus until spring when fertilization takes place (Hall and Jones 1961, Barbour and Davis 1969). Two to four pups (average of 3.4 in Florida) are born in late May and June (Jennings 1958, Barbour and Davis 1969). Young are thought to begin to fly in June or July in Texas, Louisiana, and Veracruz (Webster et al. 1980). The reproductive habits of the northern yellow bat are not known in South Carolina.

Food Habits and Foraging

Northern yellow bats are known to leave their roosts well before dark to forage (Lowery 1974). Considered a high-flying bat, this species forages 16 to 23 feet (5 to 7 m) above the ground (Barbour and Davis 1969, Schmidly 1983) in open areas such as golf courses, airports, and fields (Jennings 1958); in croplands, marshes, lake margins, and forest openings (Zinn 1977, Schmidly 1983, Krishon et al. 1997); and over piles of sawdust in Florida (Moore 1949). According to Krishon et al. (1997), the average distance of one northern yellow bat from its roost to its foraging location was 358 feet (109 m). The home range recorded for this bat was 26 acres (10.5 ha), and was located in oak habitat most of the time (73%), but was also found in loblolly and slash pine (25%) communities.

In mid to late summer in Florida, groups of young bats (mostly females) collect in feeding aggregations of greater than 100 individuals (Jennings 1958). According to a few samples, northern yellow bats have been found to feed on Coleoptera, Diptera, Homoptera, Hymenoptera, Odonata, and Zygotera (Sherman 1939, Zinn 1977). From two bats captured on Sapelo Island, Georgia, 69% of the fecal pellets were composed of Hymenoptera and 31% were Coleoptera (Carter et al. 1998). In Florida, individuals were found hunting flies and mosquitoes among beaches and dunes (Ivey 1959).

During winter, northern yellow bats are known to forage on warm nights (Jennings 1958). No foraging habits, home range or habitat use studies of northern yellow bats have been conducted in South Carolina.

Seasonal Movements

Little is known about the migration patterns of this species. Northern yellow bats may either migrate or hibernate in areas where they have been reported year round, such as in Florida (Jennings 1958) and southern Louisiana (Lowery 1974). In eastern Texas they may migrate during winter (Schmidly 1983), but in southeastern Virginia and the Coastal Plains of North Carolina they may be resident (Lee et al. 1982, Linzey 1998).

Longevity and Survival

No longevity records exist for northern yellow bats. However, due to the fact this species can have litters of three, it may live for a relatively short time compared to other bat species (Texas Parks and Wildlife Department 1994).

Threats

Threats are difficult to assess for this species because so little is known about density and population estimates, foraging habits, home range or habitat use for northern yellow bats.

Habitat and roost site loss due to development and removal of palm fronds are threats to this species (Bunch et al. 2015*c*). Residential development and citrus grove plantations may threaten this species if they result in the loss of sandhill and oak hammock habitats (Humphrey 1992). The harvesting of Spanish moss may still be a threat in some areas, but the development of synthetic materials replacing the need for Spanish moss may have reduced this threat (Trani et al. 2007). The loss of Spanish moss due to a fungal infection such as the outbreak seen during the 1960's where Spanish moss was eliminated from many areas of central Florida (Smith and Wood 1975, Jensen 1982) is a potential threat.

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to northern yellow bats because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Natural causes such as hurricanes may also lead to loss of habitat as well as direct mortality (Bunch et al. 2015*c*). Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock in South Carolina in South Carolina (Bunch et al. 2015*b*).

Collisions with wind turbines or injury from active turbines (Erickson et al. 2002, Tuttle 2004), as well as collisions with towers may also be potential threats to this species (Crawford and Baker 1981).

Conservation Measures

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to northern yellow bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to retain Spanish moss and old palm fronds on public lands to benefit northern yellow bats; encourage retention of Spanish moss and old palm fronds on private lands to benefit northern yellow bats; protect roosting areas in Spanish moss habitat; avoid removal of old palm fronds in spring when young of the year are present; work with developers and citrus grove owners to determine potential mitigation measures that minimize roost loss in sandhill and oak hammock habitats; minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); and timber management in the Piedmont region that creates uncluttered forest, such as pine thinning or controlled burns may benefit this species by creating more open forest areas. Minimize or carefully consider large-scale pesticide use whenever possible. Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible, and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to identify priority areas for field surveys of northern yellow bats; determine the distribution of this species in the Carolinas through surveys; locate northern yellow bat roosts through survey efforts and monitor those sites for use over time; conduct molecular research to determine variation within the species across its known distribution, and validate the yellow bat subspecies designation; conduct pesticide and/or heavy metal research to determine if, and how severely, northern yellow bats are affected; determine summer and winter roost site and habitat requirements for this species; determine the extent of off-shore foraging and commuting and its seasonality to assess vulnerability of northern yellow bats to off-shore wind development; and determine the vulnerability of this species, especially during fall migration, to coastal wind energy development. The SCDNR Heritage Trust tracks high priority species including the northern yellow bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees; create demonstration areas on publicly owned land by placing prominent signage in highly visible areas with old fronds left uncut that explain how old fronds provide important roosting habitat for northern yellow bats.

Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*)

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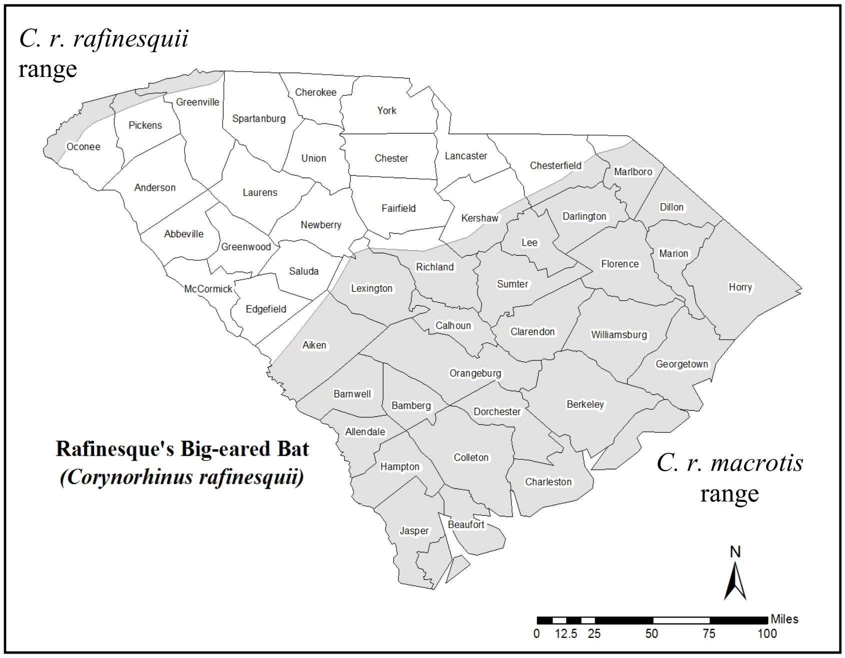
Description
An endemic to bottomland hardwood forests of South Carolina's Coastal Plain, the Rafinesque's big-eared bat has the longest ears of all bat species found in the state. Rafinesque's big-eared bats eat destructive moth larvae pests, disease-transmitting flies, and horse and deer flies (Ellis 1993, Lacki and LaDeur 2001). Though populations of this bat are not currently large enough to have a large impact (Whitaker and Hamilton 1998) they are still a main predator of these insect species. Unfortunately, loss and degradation of bottomland hardwood forest habitat has likely been a long-time driving factor contributing to the limited populations and vulnerability of Rafinesque's big-eared bats (Tiner 1984, Clark 2000, Mitsch and Gosselink 2001).

Identification
Rafinesque's big-eared bat is a medium sized bat with ears that measure 1.5 inches long. The ears are often coiled alongside the head during torpor, and take a few minutes to uncoil (inflate) when bats are disturbed (Jones 1977). Another distinctive feature of this species are the facial glands located on either side of the nose. Rafinesque's big-eared bats weigh 0.3 to 0.5 ounces (8 to 14 gr) and have a wingspan of 10 to 12 inches (26 to 30 cm) (Harvey et al. 2011). The pelage is a gray brown to dark brown above and whitish with dark rooted hairs below, and the hair on the claws extend past the toes.

Taxonomy
Two subspecies are recognized, with *C. r. rafinesquii* occupying the Ohio River valley and Appalachian mountains of North and South Carolina, and *C. r. macrotis* occupying coastal plain regions (Handley 1959). Both subspecies are found in South Carolina. However, even though two lineages exist, Piaggio et al. (2011) found that they do not correlate to subspecies within the geographical boundaries proposed by Handley (1959) (Bat Conservation International and Southeastern Bat Diversity Network 2013).

Distribution
Rafinesque's big-eared bat occurs throughout the South, ranging north to southern Illinois, Indiana and Ohio, west to southern Missouri and eastern Texas, and east to West Virginia, North Carolina, and Florida (Jones 1977, Hall 1981). This distribution has been thought to include most southern states (Harvey and Saugey 2001), but this species has yet to be found in the Piedmont of South Carolina and North Carolina (Bunch et al. 1998*a*, J. M. Menzel et al. 2003, Fields 2007, Bennett et al. 2008). *C. r. rafinesquii* is distributed within the southern Appalachian mountains from West Virginia south into South Carolina and Georgia, and *C. r. macrotis* is distributed along the Coastal Plain of North Carolina and South Carolina, and south into Georgia and Florida (Bunch et al. 2015*b*).



General Habitat

The Rafinesque's big-eared bat is usually found in mature bottomland hardwood forests of Mississippi and Ohio River valleys and the southeastern US (Brown and Brown 1993, Mirowsky 1998, Tuttle and Kennedy 2005) in stands of mature cypress (*Taxodium* species) and tupelo-gum (*Nyssa* species) (Lance et al. 2001, Trousdale and Beckett 2005, Carver and Ashley 2008). Other habitats used include open, mature, pine flatwoods in Florida and South Carolina (Brown 1997, Menzel et al. 2001*c*), mature oak-hickory forests in Kentucky (Hurst and Lacki 1999), mixed juniper (*Juniperus* species) and loblolly pine (*Pinus taeda*) habitat in Texas (Schmidly et al. 1977), and in hardwood stands surrounded by contrasting ecosystem habitats (known as hammocks) in Florida (Jennings 1958).

Population Status

Over most of its range, Rafinesque's big-eared bat is an uncommon species with scattered populations. Even though it is widespread in the South, it's not considered abundant and in the past century population levels appear to have declined (BCI and SBDN 2013). Rafinesque's big-eared bat has a rounded rank of Vulnerable both Globally (G3G4), and Nationally (N3N4), and is Subnationally Imperiled (S2?) (NatureServe 2017). However, it is currently ranked as Subnationally Imperiled (S2) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*e*). This species is listed as State Endangered, and is a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015). It is estimated that around 4,000 Rafinesque's big-eared bats hibernate in six major cave roosts in the Appalachian Mountains and central plateaus of Kentucky and North Carolina, and that smaller colonies composed of less than 50 individuals exist throughout the southeast (BCI and SBDN 2013).

Roosts and Roosting Behavior

Rafinesque's big-eared bats are primarily found in roosts in hollow trees (Trousdale and Beckett 2005, Trousdale 2011), beneath bridges (Ferrara and Leberg 2005, Trousdale et al. 2008, Loeb and Zarnoch 2011), in buildings (Clark 1990), or in sandstone caves and mines at the north end of their range (Barbour and Davis 1969, Harvey et al. 1991). Less often they can also be found in tree crevices (Lance 1999), beneath loose bark (Handley 1959), and among dead leaves (Harper 1927). With the exception of certain caves or buildings used year-round (Jones and Suttkus 1975, Clark 1990, Hurst and Lacki 1999, Finn 2000), roost sites may vary seasonally (Loeb and Zarnoch 2011, Roby et al. 2011). Because this species is not considered migratory, summer foraging grounds are usually near winter roosts.

During summer, Rafinesque's big-eared bats are primarily found roosting in hollow trees, under bark, on bridges, and in abandoned buildings (Barbour and Davis 1969, Johnson and Lacki 2011, Loeb and Zarnoch 2011). Roost trees usually stand 59 to 82 feet (18 to 25 m) tall, have large cavities greater than 3.6 feet (102 cm) tall and 1.3 feet (39 cm) wide, and tend to be near water (Mirowsky 1998, Gooding and Langford 2004, Trousdale and Beckett 2005, Carver and Ashley 2008). In South Carolina, Rafinesque's big-eared bats have been found in human-made roost towers in the Blue Ridge and Piedmont regions (Greenville and Pickens Counties), the Sandhills region (Aiken and Richland Counties), and in the Coastal Plain (Hampton County). The Coastal Plains and Sandhill populations in the state (those of *C. r. macrotis*) roost in abandoned buildings, I- and T-beam bridges, old bunkers and tunnels, and large tree cavities (Menzel et al. 2001*c*, Bennett et al. 2008, Loeb and Zarnoch 2011, Bunch et al. 2015*b*). Habitats utilized by this subspecies include black gum (*Nyssa sylvatica*) and water tupelo (*Nyssa aquatic*) stands, bald cypress (*Taxodium distichum*) swamp forests, maritime forests, and hardwood or mixed mature forested bottomlands (Cochran 1999, Hofmann et al. 1999, Lance et al. 2001, Gooding and Langford 2004, Trousdale and Beckett 2005). Loeb and Zarnoch (2011) found that anthropogenic roosts were used significantly more than tree roosts during summer in the Coastal Plain of South Carolina, and that anthropogenic roost use was higher in summer than in all other seasons. Mountain populations (those of *C. r. rafinesquii*) in summer use roosts in cavity trees such as tulip poplars (*Liriodendron tulipifera*), abandoned buildings, cave or rock shelters, and abandoned mines (Bunch et al. 1998*a*, Clark et al. 1998, Bunch and Dye 1999*a*). Habitats utilized by this subspecies include rock outcrops for roosting, mesic and cove hardwood forests, dry deciduous forests, pine woodlands, forested wetlands and bottomlands, bottomland agricultural fields, and forested riparian areas (Trousdale and Beckett 2002, 2004, Johnson and Lacki 2013, Bunch et al. 2015*b*). Bennett (2006) found that though Rafinesque's big-eared bats occupied bridges in the Upper and Lower Coastal Plain, they were absent from bridges in the Piedmont and Blue Ridge Mountains.

In spring during inclement weather, adult females have been known to enter shallow torpor before parturition takes place, with solitary individuals being observed in torpor more often than those in clusters (Clark 1990). However, males and non-reproductive females are still known to enter more daily torpor bouts than reproductive females (Johnson et al. 2012).

Nursery colonies form in spring between early April and late May (Jones and Suttkus 1975, Clark 1990), typically on vertical surfaces inside trees (Carver and Ashley 2008, Stevenson 2008), caves, mines, or other karst features (Barbour and Davis 1969, Harvey et al. 1999*a*). The size of summer colonies can range from a couple to 50, and sometimes even up to 300 (BCI and SBDN 2013). Roost tree density affects the social structure of Rafinesque's big-eared bats, where lower densities may lead to the use of only one focal maternity roost (Johnson et al. 2012). Though some reproductive males have been found roosting with pregnant and lactating females, the majority of adult males roost alone during summer (Hurst 1997). In South Carolina, maternity colonies have been found in abandoned buildings in Aiken County (M. A. Menzel et al. 2003), a gold mine in Oconee County, bridges (Bennett et al. 2003*b*), and in tree cavities with approximately 100 individuals at Congaree National Park (National Park Service 2004).

In mid-August, female clusters are joined by other individuals after the nursing period (Hall 1963, Barbour and Davis 1969, England et al. 1990), though rarely do they include males (Clark 1990). From September through October, nursery colonies disperse (Jones and Suttkus 1975, Clark 1990). In the coastal plains, warmer buildings and trees are left behind in search of microclimates that have a cooler and more stable temperatures such as cooler trees (Clark 1990, Rice 2009), cisterns and abandoned water wells (Schmidly 1983). Rafinesque's big-eared bats are considered sedentary because they haven't been found any further than 2.1 miles (3.4 km) from primary roosting sites in bottomland forests (Finn 2000, Johnson and Lacki 2011) and 1.6 miles (2.6 km) (England and Saugey 1998, Hurst and Lacki 1999, Lance et al. 2001) from roosting sites in upland forests.

During winter in the northern portions of its range, this species hibernates for short periods of time and is known to move between roost sites (Hoffmeister and Goodpaster 1963, Jones and Suttkus 1975, Hurst and Lacki 1999). Generally, this species is found hibernating in mines, caves, cisterns, and wells (Barbour and Davis 1969, England and Saugey 1999, Harvey et al. 1999*a*) from November to March (England et al. 1990, Whitaker and Hamilton 1998). However, they have also been found roosting in buildings year round in North Carolina (Clark 1990). In the South, Rafinesque's big-eared bats enter torpor when the weather turns cold (Jones and Suttkus 1975), but are otherwise thought to be active year round (Ferrara and Leberg 2005). In the Coastal Plain where caves, mines, or other karst features are unavailable, this species may remain in large hollow trees of closed canopy bottomland hardwood forests. Rafinesque's big-eared bats also adjust roosting height seasonally in trunk hollows, moving from the bottom of the tree cavity to the top during winter (Rice 2009). Alternatively, this species may choose larger diameter trees in winter than in spring and summer, as they've been known to do in the bottomland hardwood forests of Mississippi (Fleming et al. 2013). In South Carolina, Rafinesque's big-eared bats have been found using a gold mine in Oconee County and abandoned buildings in Aiken County as hibernacula. They've been known to use a different location within these same sites for a maternity roost or hibernacula, depending on the season.

There is evidence that this species switches roosts often but still has high site fidelity to groups of hollow trees (Gooding and Langford 2004, Trousdale and Beckett 2005, Johnson and Lacki 2011, Trousdale 2011), and roost sites beneath bridges (Ferrara and Leberg 2005, Trousdale et al. 2008, Loeb and Zarnoch 2011). Rafinesque's big-eared bats that roost beneath the same bridges are thought to also frequently use other roosts (Ferrara and Leberg 2005, Bennett et al. 2008). These movements, as well as clustering, seem to be correlated with air temperature (Hoffmeister and Goodpaster 1963, McNab 1974, Jones and Suttkus 1975). For undisturbed bats living in buildings, roost switching is relatively rare (Clark 1990).

Reproduction

Though there have been reports of individuals breeding in mid-February and mid-March (Goodpaster and Hoffmeister 1952, Clark 1990), mating is generally thought to occur in the fall and winter, and sperm is stored in the female's uterus until spring when fertilization takes place (Hoffmeister and Goodpaster 1963, Barbour and Davis 1969). A single pup is usually born between mid-May in the deep-south, or late-May to early June in the northern portion of their range (Jones 1977, Harvey et al. 1999*a*). The gestation period from one report of a captive female was 93 days (Clark 1990). Females may carry young from one roost to another, adding an additional 66% of their own body weight (Jones and Suttkus 1971, England et al. 1990). Young begin to fly after three weeks (Jones 1977). It is not until their second year that males become sexually mature (Jones and Suttkus 1975, England et al. 1990).

Food Habits and Foraging

This species may emerge late in the evening to forage (Harvey et al. 1999*a*), though in South Carolina they have been found to emerge not long after sunset until around midnight before emerging again to forage a few hours before sunrise (Menzel et al. 2001*c*).

The Rafinesque's big-eared bat is a highly maneuverable flier that can navigate well in dense vegetation and hover in place (Belwood 1992), often foraging about 3 feet (1 m) from the ground gleaning insects from foliage (Barbour and Davis 1969, Clark 1991, Ellis 1993). In North Carolina, this species avoided large open areas such as fields, roadways, and open water (Clark 1990, 1991). Large nursery colonies have been reported to forage along mid-slope ridges in mature oak-hickory forests of Kentucky (Hurst and Lacki 1999). In South Carolina, swamp forests represented the majority of the area used by radio-tagged bats in the forested old growth swamp at Francis Beidler Forest (Clark et al. 1998). At the Silver Bluff Plantation in the Upper Coastal Plain, reproductive males fed in uplands in young pine stands where sapling stage stands were preferred over sawtimber stands, despite the fact that mature bottomland hardwoods were common in the study area (Menzel et al. 2001*c*). Rafinesque's big-eared bats in the mountains of South Carolina that had been captured and fitted with radio transmitters in the Eastatoe Valley foraged in and around forested bottomlands and a cornfield in Eastatoe Valley (Mary Bunch, SCDNR, pers. comm.). In Kentucky, this species was found closer to upland deciduous forest and forested and herbaceous wetlands than agricultural areas and open fields (Johnson and Lacki 2011). Also during this study, pregnant females traveled from forested wetland roost sites to foraging sites in deciduous forests on dry soil with rich Lepidoptera abundance. In Florida, wetland and pastures were preferred over palmetto and non-forested wetlands (Finn 2000), though foraging areas varied seasonally as forested wetlands were used from November to February and upland oak forests from August to April. In South Carolina, this species has been found foraging less than 0.62 miles (1 km) from roosting sites in an average home range area of 230 acres (93 ha) in the Upper Coastal Plain (Menzel et al. 2001*c*). This differs from the Francis Beidler Forest study in the Outer Coastal Plain, which found a smaller average home range of 190 acres (77 ha). Studies in Kentucky show similar distances from roosting sites to foraging areas as Menzel et al. (2001), but foraging areas averaged even larger at 352 acres (143 ha) (Hurst and Lacki 1999). The activity of Rafinesque's big-eared bats has been recorded in July in South Carolina in July at the Bad Creek Hydroelectric Project, Eastatoe Creek, and shoreline on Lake Jocassee on the west side of Double Spring Mountain (Webster 2013).

Lepidoptera is the primary food source of Rafinesque's big-eared bats in South Carolina and elsewhere (Donahue 1998, Menzel et al. 2002*a*, Armbruster 2003, Lacki et al. 2007), with moths comprising the vast majority of prey consumed in Kentucky (Hurst and Lacki 1997). Hurst and Lacki also reported Coleoptera, Homoptera, Diptera, Hemiptera, Hymenoptera, and Trichoptera as other insects consumed, in decreasing volume. A variety of moth species are consumed by Rafinesque's big-eared bat, seen by the 22 species from six families reported by Lacki and LaDeur (2001). In North Carolina, almost one third of the diet of this species consisted of horse and deer flies (Ellis 1993).

Seasonal Movements

Rafinesque's big-eared bats are considered sedentary, as their summer foraging grounds are usually near winter roosts and they haven't been found any further than 2.1 miles (3.4 km) (Finn 2000, Johnson and Lacki 2011) from primary roosting sites.

Longevity and Survival

The longest lived Rafinesque's big-eared bat was a banded individual in West Virginia reported at 10 years old (Paradiso and Greenhall 1967). Juvenile mortality for this species varies across studies, but in South Carolina the rate has been reported as high as 40 to 60% (Armbruster 2003).

Threats

Since 1975, populations of Rafinesque's big-eared bat have been declining in some areas (Jones and Suttkus 1975). Mortality on this species is not well documented, but the loss of roosting habitat, vandalism by humans, predation, and flooding are reported most frequently (Clark 1990, Finn 2000, Bennett et al. 2004). Disturbance at roost and maternity sites in caves, buildings, and rock shelters also threatens Rafinesque's big-eared bats (Clark 1990, Lacki 2000).

Loss and degradation of bottomland hardwood forest habitat through clearing and drainage, coupled with the disappearance of extra large tree hollows, has likely been the major threat and long-time driving factor contributing to limited populations and vulnerability of Rafinesque's big-eared bats (Tiner 1984, Clark 2000, Mitsch and Gosselink 2001). Loss of forest woody plant diversity necessary for the development of the main prey species of these bats may threaten their survival as well (Dodd et al. 2008, 2012, Lacki and Dodd 2011). Destruction and fragmentation of mature forests in the mountains and Coastal Plain is another potential threat (Bunch et al. 2015*b*). Additionally, the loss of human-made structures that more recently took the place of tree hollows as colonial roosts may be a problem in some areas (Clark 1990, Belwood 1992, Lance 1999).

Rafinesque's big-eared bat may be particularly vulnerable to pesticides given its reliance on moths (Hurst and Lacki 1999, Lacki and LaDeur 2001). Pesticides have been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982), and can alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).
Potentially, deforestation from gypsy moths (*Lymantria dispar*) and/or control measures for gypsy moths, such as broadcast usage of *Bacillus thurinigiensis* var. *kurstaki* may impact this bat species, as well as heavy metals (Bunch et al. 2015*b*).

The genetic isolation of populations is another threat to Rafinesque's big-eared bats (Bunch et al. 2015*b*). Due to the fact that populations are becoming smaller and more isolated, this species has also become more vulnerable to natural threats such as hurricanes (Clark 2000).

Other potential threats reported by Bunch et al. (2015*b*) include alteration of natural flood regimes that may affect the regeneration of important forest community types such as cypress-gum, thus preventing recruitment of future roost trees. These alterations may also flood natural roosts. Abundant invasive exotic vegetation, such as some privet species, may

prevent the regeneration of forest species and impair recruitment of suitable roost trees. Additionally, feral cats also pose a threat as unnatural predators at roosts.
The inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species, may be another threat to Rafinesque's big-eared bat. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011).

WNS could be a potential problem, as it has been detected on Rafinesque's big-eared bats. However, this species has not yet shown diagnostic sign of the disease (White-nose Syndrome.org 2015).

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock in South Carolina (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to Rafinesque's big-eared bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and structures that mimic large hollow trees such as large bat towers may be a suitable alternative for Rafinesque's big-eared bats.

Conservation measures include conserving old-growth forests and reestablishing corridors connecting suitable habitat (Clark 2000); protecting mature bottomland hardwood forests and recruitment of younger stages of high quality bottomland habitat for growth into future roost trees; and providing artificial roosts in areas of depleted roosting resources (Clark and Williams 1993).

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include continuing long-term monitoring of bridges in the Coastal Plain for Rafinesque's big-eared bats; continue long-term monitoring of Rafinesque's big-eared bat roosts in the mountains; determine if prescribed fire represents any threat, and also determine the acceptable distance of fire, smoke and fire lines from roosts; determine the genetic structure of selected colonies and test whether populations are experiencing adverse genetic consequences from isolation and fragmentation; survey and map mines, tunnels, wells and cave-like structures not surveyed in previous efforts; obtain long-term demographic data including reproductive success, sex ratios, survival, immigration and emigration facilitated by dispersal, and determine the effects of biotic and abiotic factors on these parameters; determine if unnatural predation at roosts by feral cats is occurring; determine alternate roost sites for bridge roosting individuals; locate and map roost trees by physical searches where possible; determine foraging habitat requirements (habitat types, size, and distance from roosts); use existing data on habitat preferences to identify the availability of natural roost habitat and to determine the amount of protected versus unprotected habitat; determine the effects of habitat fragmentation and roads on foraging behavior of Rafinesque's big-eared bats; study the feeding ecology requirements in the mountains and Coastal Plain; conduct seasonal surveys at caves and mines being considered for closure; and evaluate roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. The SCDNR Heritage Trust tracks high priority species including Rafinesque's big-eared bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Seminole Bat (*Lasiurus seminolus*)

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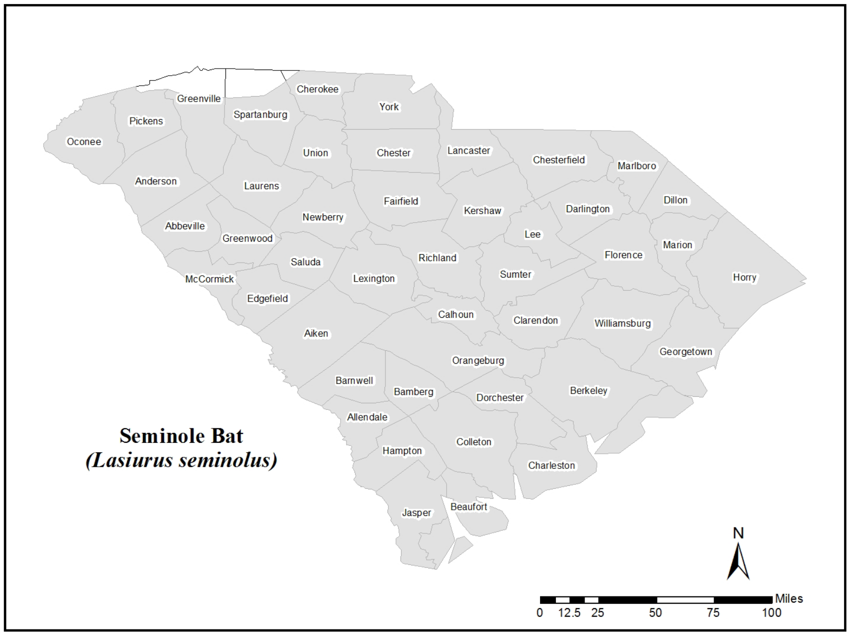
Description
Throughout the southeast, the Seminole bat is one of the most common bats seen flying in the evening, especially on warm winter nights (Harvey et al. 2011). As with the northern yellow bat, this species roosts in Spanish moss (*Tillandsia usneoides*) and therefore is very closely associated with lowland wooded areas where Spanish moss occurs (Barbour and Davis 1969). The Seminole bat was once considered to be a subspecies of the eastern red bat (*Lasiurus borealis*) due to its similar size and appearance, but the color of the pelage distinguishes these species, as eastern red bats are more brick red in color.

Identification
The Seminole bat is a medium sized bat with a rich mahogany pelage frosted with white tips above, and slightly paler below. This species weighs 0.3 to 0.5 ounces (9 to 14 gr) and has a wingspan of 11 to 12 inches (29 to 31 cm) (Harvey et al. 2011). Their furred ears are short and rounded, and the tail membrane is furred to the tip of its tail. The wings of this species are long and pointed. They are similar to eastern red bats in that they have distinctive white patches on the wrist and shoulder.

Taxonomy
The Seminole bat is considered monotypic (Wilson and Reeder 2005).

Distribution
Seminole bats typically range from the southeastern tip of Virginia south to Florida, west to east Texas along the Gulf Coast States, and north to southeastern Oklahoma and southern Arkansas (Wilkins 1987). There are a few isolated records as far north as New York and Pennsylvania (Poole 1949, Layne 1955). In South Carolina, this species is commonly found in the upper and lower Coastal Plain, but there are also a few fall and summer records in the Piedmont and Blue Ridge regions (M. A. Menzel et al. 2003).

Population Status
Considered common throughout the Deep South, the Seminole bat is ranked as Globally Secure (G5), Nationally Secure (N5) and Subnationally Unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Apparently Secure (S4?) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Timm and Arroyo-Cabrales 2008). There are no population density estimates for this species, though in suitable habitat it is thought to be abundant (Barbour and Davis 1969, Lowery 1974, Webster et al. 1985, Schmidly 1991). The Seminole bat is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due in part to severe WNS-related mortality occurring in other bat species



General Habitat
Seminole bats are found in lowland wooded areas where Spanish moss occurs, often in mature pine-dominated forest such as pine-oak (*Pinus-Quercus*) and longleaf pine (*P. palustris*), mixed pine-hardwood, upland hardwood forests, islands, prairies, shrub swamp, blackgum (*Nyssa sylvatica*) forest, pure bay forest, bald cypress (*Taxodium distichum*) and pure and mixed cypress (Laerm et al. 1980, Menzel et al. 1998, 1999*a*, 2000*a*, Perry and Thill 2007*a*, Hein et al. 2008*b*).

Roosts and Roosting Behavior
Seminole bats roost solitarily, commonly in oak hammock communities in Spanish moss from fall through spring and even during winter (Constantine 1958, Jennings 1958, Barbour and Davis 1969), but also in the canopy of live pine trees (Menzel et al. 1998, 1999*a*, 2000*a*, Perry and Thill 2007*a*). This species may also opportunistically roost in mines or caverns (Heath et al. 1983). Roost sites are often selected with west and southwest exposures that are thought to provide warmth from the sun (Constantine 1958, Wilkins 1987). Seminole bats may roost at heights great enough to drop into unobstructed space in order to take flight, which vary from 3.6 to 14.8 feet (1.1 to 4.5 m), but may roost closer to the forest floor during colder weather (Constantine 1958).

During summer, this species primarily roosts in Spanish moss (Barbour and Davis 1969), and sometimes under loose bark (Sealander 1979). In South Carolina, they also roost in the terminal branches of pine limbs in pine dominated communities (Menzel et al. 1998), and at the Savannah River Site roosts were primarily located in loblolly pines (*Pinus taeda*) (Menzel et al. 2000*a*). In the latter study, roosts tended to be in taller, larger trees found in areas with higher basal area, lower species richness understory, and less Spanish moss than neighboring trees. Also in this study, Seminole bats showed low roost site fidelity as they stayed at each roost tree for an average of 1.7 days, but relatively high site fidelity as they switched to new roost trees within 0.62 acres (0.25 ha) area of their home range. This suggests that stand and landscape features may be influence roost-site selection more than tree and plot characteristics (Lunney et al. 1988, Cryan et al. 2001, Elmore et al. 2004).

In the lower Coastal Plain of South Carolina, Seminole bats roosted exclusively in the canopy of live loblolly pines and proximity to habitat edge was negatively related to both male and females (Hein 2008). Other studies show that Seminole bats may often switch roosts but go back to trees or roost sites previously used (Perry and Thill 2007*a*, Hein et al. 2008*b*). According to another study in South Carolina by Hein et al. (2008*b*), 63% of males and 61% of female roosts were found in forested corridors, with differences in habitat selection between the sexes and reproductive condition. Males chose sites nearest corridors and open stands, and roosts were evenly distributed among mid-rotation, mature pine, and mixed pine-hardwood stands. Nonreproductive females selected sites nearest corridors and forest edges, but did not select for a particular stand type. Reproductive females chose sites nearest forested edge and mature pine stands, with roosts found primarily in mature pine habitat, and larger and taller trees selected for than males or nonreproductive females. Increased solar exposure from these roosts may play a factor in roost selection as they are beneficial to the growth of prenatal and juvenile bats (Racey and Swift 1981, Vonhof and Barclay 1996, Willis and Brigham 2005).

During winter, Seminole bats may have a basal metabolic rate that resembles hibernation (Genoud 1990). However, they do not enter a deep torpor lasting the entire season but arouse and forage on warm nights, especially in the southern parts of their range (Wilkins 1987). In Florida, they don't generally fly when temperatures are less than 64°F (18°C) (Jennings 1958). This species commonly utilizes oak hammock communities in Spanish moss during winter (Constantine 1958). In South Carolina, males have also been known to roost in overstory trees and clusters of pine needles, understory vegetation, and found in leaf litter on the forest floor for up to 12 consecutive days during colder winter weather (Hein et al. 2005, 2008*b*). Male Seminole bats were reported as selecting taller trees in mature forest stands on warmer winter nights, but when minimum nightly temperatures were less than 39°F (4°C), they typically roosted in mid-rotation stands on or near the forest floor (Hein 2008).

Reproduction

Mating usually occurs in the fall, and probably in winter and spring (Constantine 1958), and sperm is stored in the female's uterus until spring when fertilization takes place. Twins are usually born between late May and June (Davis 1974). Pregnant females have been collected in May in South Carolina, Alabama, and Florida (Barkalow 1948, Moore 1949, Coleman 1950, Jennings 1958), and a lactating female was found as far north as New Hanover County in North Carolina (Barkalow and Funderburg 1960). Gestation lasts between 80 to 90 days, young are weaned and begin to fly at three to four weeks, and are probably sexually mature at the end of their first year (Barbour and Davis 1969, Wilson and Ruff 1999). Young bats also have a tendency to wander extensively after being weaned (Barbour and Davis 1969). The reproductive habits of the Seminole bat in South Carolina are unknown.

Food Habits and Foraging

Seminole bats are fast, direct flyers that forage at dusk. They feed at treetop level around 20 to 50 feet (6 to 15 m), 65 to 164 feet (20 to 30 m) above open water and along edges of cypress swamp, or glean prey from leaf surfaces or even the ground (Sherman 1935, Barbour and Davis 1969, Zinn 1977). They are also known to forage over forest clearings, woods, pine barrens, upland and bottomland hardwoods habitat and corridors, and sometimes coastal prairies and hammocks (Harper 1927, Menzel et al. 2002*b*, 2005*a*, *b*, Carter et al. 2004). However, their activity did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005) despite being considered a clutter-adapted species.

At the Savannah River Site in South Carolina, habitat types selected included 55% pine forests, 35% bottomland hardwoods, and 11% upland hardwoods (Carter et al. 2004). Foraging areas may not encompass roosting areas (Krishon et al. 1997), and may be relatively large. The home range size of five Seminole bats at the Savannah River Site averaged 1,045 acres (423 ha), ranging from 467 to 1,739 acres (189 ha to 704 ha) (Carter 1998). Hein et al. (2008*b*) reported that bats typically roosted in the same stand for the duration of the transmitter and that the mean roosting home range was 1.1 acres (0.46 ha) for males, 14.5 acres (5.85 ha) for reproductive females, and 0.5 acres (0.22 ha) for nonreproductive females.

Prey for this species include insects primarily from Coleoptera, Odonata, and Hymenoptera, but also Homoptera, Diptera, and Lepidoptera (Sherman 1935, Zinn 1977, Carter 1998, Donahue 1998, Carter et al. 2004). Seminole bats also opportunistically consume insects attracted to street lights (Jennings 1958).

Seasonal Movements

Seminole bats are thought to be mostly resident within their range, and are active during winter when the weather is warm enough (Jennings 1958). They have been reported year round in Texas, South Carolina, and Florida (Moore 1949, Coleman 1950, Schmidly et al. 1977). Seasonal migration is also thought to occur within their range, as the abundance of this species increases in the southern portion and decreases in the northern portion (Kunz and Racey 1998, Wilhide et al. 1998). However, no evidence has conclusively demonstrated that Seminole bats have migratory behavior (Wilkins 1987) and unusual occurrences of individuals outside the known range may have to do with the tendency for young to wander (Barbour and Davis 1969).

Longevity and Survival

The longevity and survival of Seminole bats is unknown. A higher mortality rate of males has been observed, as fewer males have been recorded in the older age class than females. As with many bats, juvenile Seminole bats most likely have a higher mortality than adults (Kunz and Racey 1998).

Threats

Wind energy may pose a small threat to Seminole bats, as fatality of this species at a wind power development at Buffalo Mountain Windfarm, Tennessee has been documented (Fiedler 2004, Johnson 2005). However, the fatalities reported are extremely low compared to those in migratory tree bats at wind-energy facilities. No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Additionally, deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981). However, the level of impact from tower mortalities on local or range wide populations remains unclear.

Habitat and roost site loss due to development and removal of palm fronds are other potential threats for this species. The loss of Spanish moss due to a fungal infection such as the outbreak seen during the 1960’s where Spanish moss was eliminated from many areas of central Florida (Smith and Wood 1975, Jensen 1982) is a potential threat. The harvesting of Spanish moss may still be of concern in some areas, but the development of synthetic materials replacing the need for Spanish moss has generally reduced this threat (Trani et al. 2007). Also, natural causes such as hurricanes may also create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Conservation Measures

Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to Seminole bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations from Bunch et al. (2015*c*) include working to retain upland forest corridors to prevent isolation of Seminole bats; minimize bat mortality during prescribed burn activities by burning in the spring or summer; advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C) and temperatures at the time of ignition are > 50°F (10°C); maintain hedgerow habitats along crop borders; retain large trees in urban areas, and Spanish moss and old palm fronds on public lands; and timber management in the Piedmont region that includes pine thinning or controlled burns may benefit this species by creating more open forest areas. Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible, and protect habitat above or around maternity roosts and known foraging areas from pesticides. Additionally, management that provides suitable roosts include long rotations, complex canopy structure, and allowing snags to form (Menzel et al. 2000*a*), keeping in mind that pine plantations do not provide suitable roosting habitat due to lack of appropriate substrate such as foliage and tree cavities (Kern and Humphrey 1995).

Priority survey and research recommendations from Bunch et al. (2015*c*) include conducting further research to better understand general habitat requirements, population status, summer and winter roost sites, winter habitat, migration information, and behavior of Seminole bats; determine the extent and seasonality of off-shore commuting and foraging to assess vulnerability of Seminole bats to off-shore wind development; and determine the vulnerability of Seminole bats, especially during fall migration, to coastal wind energy development. Researchers are requested to collect and record bat data, but the SCDNR Heritage Trust does not track this species in its database.

Education and outreach goals recommended by Bunch et al. (2015*c*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans; and discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees.

Silver-haired Bat (*Lasionycteris noctivagas)*

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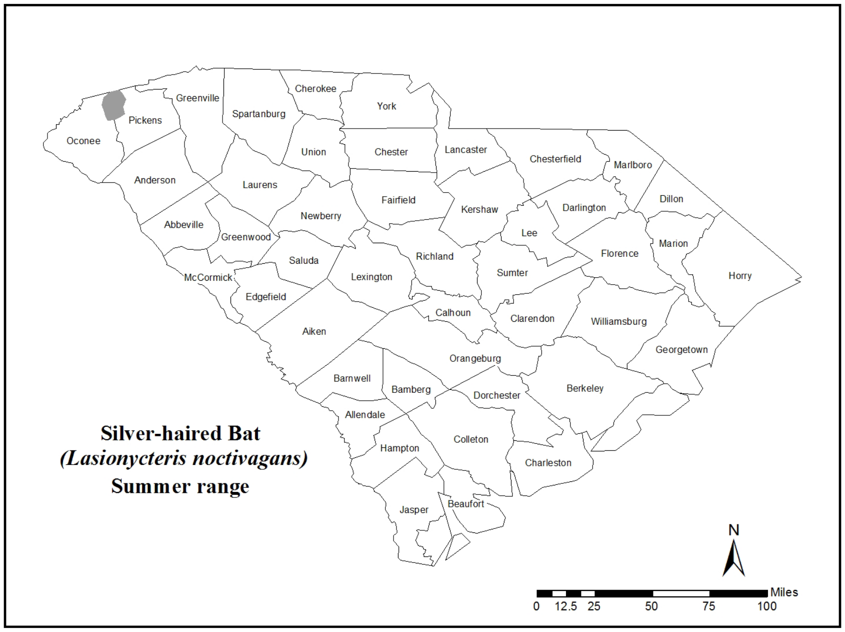
Description
One of the most common bats found in forested habitats across most of the US, the silver-haired bat is easily recognized by its blackish-brown pelage with silvery-white tips above, and paler with less pronounced frosting below. This solitary tree roosting bat is highly dependent upon old-growth forests, and one of the slowest flying bats in North America with a flight speed of 10.7 to 11.2 miles per hour (17.28 to 18 kmph) (Naumann 1999). Silver-haired bats migrate from northern areas during fall to more southern locations to hibernate in caves at 28.4 to 31.1°F (-.05 to -2°C), and/or use daily torpor interspersed with bouts of foraging in warmer areas (Humphrey 1975, Nagorsen and Brigham 1993, Dunbar 2007, Falxa 2007). These seasonal migrations can be quite extensive. For example, McGuire et al. (2012) predicted that this species could travel approximately 932 miles (1500 km) from the north side of Lake Erie to the southeastern US in five to six nights without refueling.

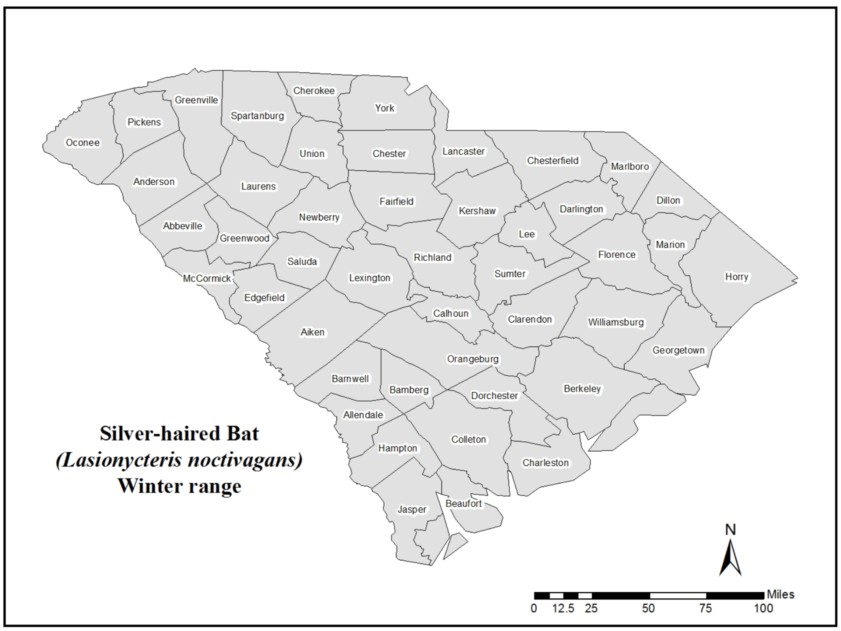
Identification
This medium sized bat has black ears that are hairless, rounded and short with a blunt tragus. The wing and tail membranes are black, and the basal upper half of the outside of the tail membrane is densely furred. The frosted appearance of the pelage in this bat is less pronounced in older bats. This species weighs 0.3 to 0.4 ounces (8 to 11 gr) and has a wingspan of 11 to 12 inches (27 to 31 cm) (Harvey et al. 2011).

Taxonomy
The silver-haired bat is considered a monotypic species (Wilson and Reeder 2005).

Distribution
The silver-haired bat is distributed throughout southern Canada and most of the US, reaching its southern limit in the Southeast and Southwest (Kunz 1982*a*). In South Carolina, this species is distributed statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003). However, this distribution may vary seasonally since individuals are known to migrate. During the winter they are distributed statewide, but during summer they are not generally found in the lower Piedmont or Coastal Plain (M. A. Menzel et al. 2003, Bunch et al. 2015*a*).

Population Status
Considered widespread in the US, though perhaps erratic in abundance (Barbour and Davis 1969), the silver-haired bat has a rounded rank of Globally Vulnerable (G3G4), Nationally Secure (N5) and is Subnationally Unranked (SNR) (NatureServe 2017). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales et al. 2008*b*). However, this species is listed as a Highest





Priority species in the South Carolina 2015 SWAP (SCDNR 2015), due to severe WNS-related mortality occurring in other bat species, and the fact that *P.d.* has been detected on silver-haired bats but no diagnostic sign of WNS has been documented.

General Habitat

This species is typically found in forests and riparian zones including those in deciduous, coniferous, and mixed coniferous types adjacent to water (Kunz 1982*a*, Whitaker and Hamilton 1998, Nowak 1999). Old-growth habitats with more diverse structure tend to be preferred for both roost availability and foraging suitability (Thomas 1988, Jung et al. 1999). In Washington, silver-haired bats also occur in suburban and developed areas (Johnson and Cassidy 1997), and in Oregon are generally only found in shrub-steppe habitat during migration (Whitaker et al. 1981, Perkins and Cross 1988). The elevation range at which this species is found is between sea level to at least 6,000 feet (1,830 m) (Nagorsen and Brigham 1993, Christophersen and Kuntz 2003, Petterson 2009).

Roosts and Roosting Behavior

Silver-haired bats have been found roosting in trees (Cowan 1933, Jackson 1961), buildings (Frum 1953, Clark and Williams 1993), rock crevices (Frum 1953), and caves and mines (Beer 1956, Layne 1958, Pearson 1962, Baker 1965, Turner 1974). They have shown a roosting preference for forests with large numbers of snags (Campbell et al. 1996, Mattson et al. 1996, Betts 1998) and old-growth forests (Thomas 1988, Jung et al. 1999). There have been no studies investigating the roosting habits of silver-haired bats in South Carolina.

During summer, roosts and nursery sites are often found in tree foliage, under loose bark, in narrow crevices in tree trunks, or in old woodpecker cavities (Parsons et al. 1986, Betts 1996, Mattson et al. 1996, Vonhof and Barclay 1996). In Washington, roosts included dead or dying trees with exfoliating bark, extensive vertical cracks, or cavities, and were significantly taller than surrounding trees with less overstory, less understory, and shorter understory vegetation than comparable random plots (Campbell et al. 1996). In the same study, the height of summer roosts ranged between 20 to 50 feet (6.1 to 15.2 m). In southern British Columbia, silver-haired bats spent significantly more residence time in cavity roosts (14 days) than bark roosts (6 days), potentially due to cavity roosts containing maternity colonies (Vonhof and Barclay 1996). Where relatively large numbers of this species are found, populations are dominated by females during summer except in the montane west (Kunz 1982*a*).

Maternity colonies are relatively small on average, normally ranging from five to 25 females but sometimes up to 70 individuals (Rainey and Pierson 1994, Mattson et al. 1996, Vonhof and Barclay 1996). Maternity roosts are usually found in old woodpecker cavities (Parsons et al. 1986, Mattson et al. 1996, Vonhof and Barclay 1996) and in taller trees with retained tops protruding above the canopy (Betts 1998), possibly in order to better absorb sunlight and retain heat. In the study by Betts (1998), roost fidelity varied from the use of one to two roosts for eight to 13 days, or five to six roosts for one to six days, and colonies tended to stay together when switching between roosts.

Males and non-reproductive females generally roost alone (Humphrey 1975, Barclay et al. 1988, Betts 1998), and may switch roosts as often as every day (Campbell et al. 1996, Mattson et al. 1996). Day roosts of these individuals have been found in cavities as well as under loose bark on large trees in intermediate stages of decay (Mattson et al. 1996).

During late summer and early fall, migrating bats have been known to roost in narrow crevices in tree trunks (Barclay et al. 1988), and in trees and human-made structures such as buildings, lumber piles, utility poles, fence posts, and mines (Barbour and Davis 1969, Nagorsen and Brigham 1993, McGuire et al. 2012). Barclay et al. (1988) reported the height of roosts for migrating silver-haired to be between 2.9 to 11.5 feet (0.87 to 3.5 m) in Manitoba. In the same study, bats were located in trees with significantly larger circumferences than random samples. In Manitoba, 18 individuals of this species were found to be torpid for several days at temperatures below 68°F (20°C) during migration (Barclay et al. 1988).

During winter, large populations of this species migrate south to areas above a 20°F (-6.7°C) mean daily minimum temperature isotherm for January (Izor 1979). However, individuals may also hibernate in stable microclimates during winter to maintain energy, such as in caves at 28.4 to 31.1°F (-.05 to -2°C), and/or use daily torpor interspersed with bouts of foraging (Humphrey 1975, Nagorsen and Brigham 1993, Dunbar 2007, Falxa 2007). This species roosts alone or in small groups in hollow trees, under loose bark, at ground level, in houses, and sometimes in caves, abandoned mines, rock crevices, and rock outcrops (Kunz 1982*a*, Maser 1998, Perry et al. 2010). Perry et al. (2010) found that 90% of winter roosts were in five species of trees, and most were on southern topographic aspects. Of all roosts, 55% were under loose bark, 6% were either under a tree roost or in a cavity at the base of a live pine, and 3% were found in a rock outcrop, often on days colder than 41°F (5°C). Pine or pine-hardwood stands greater than 50 years old and used forest stands between 15 and 50 years old were selected as winter roosts by silver-haired bats in this study.

Reproduction

Mating probably occurs in the fall and winter, and sperm is stored in the female's uterus until spring when fertilization takes place between late April and early May (Druecker 1972, Kunz 1982*a*). Twins are usually born between June and July (Merriam 1884, Easterla and Watkins 1970, Kunz 1971). Gestation lasts 50 to 60 days, lactation lasts about 36 days and young begin to fly between three to five weeks (Kunz 1971, Druecker 1972, Nagorsen and Brigham 1993). Most males and females are thought to reach sexual maturity in their first year (Druecker 1972, Cryan et al. 2012).

Food Habits and Foraging

The silver-haired bat often emerges later in the evening after other species have left to forage (Seton 1907, Bailey 1929, Kunz 1973), and foraging activity has been shown to peak two to four hours after sunset and six to eight hours after sunset (Jones et al. 1973, Kunz 1973). This species has short, broad wings and a slow, agile flight of 10.4 to 11.2 miles per hour (4.8 to 5 mps) (Hayward and Davis 1964, Whitaker et al. 1977, Naumann 1999), and captures small insects at close range (Barclay 1985, Nagorsen and Brigham 1993).

Foraging habitats include mixed deciduous forests, coniferous forests, and riparian habitats next to or over bodies of water such as streams and ponds (Kunz 1982*a*). The silver-haired bat has been recorded as foraging in an area of about 151 to 299 feet (46 to 91 m) in diameter (Schwartz and Schwartz 1959). During migration, this species forages along intact riparian areas in arid rangelands of Oregon (Whitaker et al. 1981). In winter, foraging activity of silver-haired bats occurs during mild temperatures on rainless nights in Washington (Falxa 2007), and in Virginia and North Carolina they are active at 55°F (13°C) or more (Padgett and Rose 1991). In South Carolina, the activity of silver-haired bats has been recorded widely around Lake Jocassee and Lake Keowee in April, July and October at 27 of the 31 sites surveyed (Webster 2013).

Primary prey consumed by this species are generally moths (Black 1974), but also include other species from Lepidoptera as well as those from Hemiptera, Coleoptera, Diptera, Isoptera, and Trichoptera (Jones et al. 1973). Specimens from Indiana contained 90 to 100% Trichoptera and 10% Coleoptera, and those from Oregon contained 32% Lepidoptera, 15% Isoptera, and 26% Diptera (Whitaker 1972, Whitaker et al. 1977).

Seasonal Movements

Silver-haired bats are migratory over much of their range. This range is thought to shift to the north in the spring and to the south in the fall, though the southern shift appears to be more extensive in eastern than western North America (Baker 1978, Izor 1979). Females migrate further than males, and males are only present throughout the range during migration (Kunz 1982*a*). The timing of fall migration has been recorded to occur in two waves, primarily from August through September (Barclay 1984, Arnett et al. 2008, McGuire et al. 2012). In eastern North America, McGuire et al. (2012) predicted the fall migration rate of silver-haired bats from the north side of Lake Erie to the southeastern US be 155 to 170 miles (250 to 275 km) per night for five to six nights without refueling, even though brief stopovers of one to two days do occur. However, migrating individuals do engage in feeding activity, especially on non-travel nights (Reimer et al. 2010, McGuire et al. 2012). Spring migration also happens in waves, and occurs along the southern shore of Lake Manitoba is in May and early June (Barclay et al. 1988).

Longevity and Survival

In a study by Schowalter et al. (1978), most individuals were estimated at two years old with the oldest being 12 years old.

Threats

Wind turbine facilities are the biggest major threat to this species as they are one of the species most commonly killed at wind farms in North America, composing about one-fifth of an estimated 450,000 bat fatalities at wind facilities annually (Cryan 2011, Ellison 2012). Because the silver-haired bat is one of three migratory tree bats that compose the majority of wind turbine fatalities, it has been suggested that seasonality and migration patterns make them more vulnerable to collisions (Cryan 2011). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*). Collisions with towers may also be a threat, as it has been with other foliage roosting bats in Florida (Crawford and Baker 1981).

Loss of roost habitat due to development and forestry practices may threaten populations of silver-haired bats. For example, the loss of existing snags and curtailed development of large snags from forestry practices means less maternity and roosting sites (Campbell et al. 1996, Mattson et al. 1996, Betts 1998). Loss of migration roosts and foraging habitat in riparian areas is another potential threat. Also, natural causes such as hurricanes may create loss of habitat as well as direct mortality (Bunch et al. 2015*c*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). This species may additionally be vulnerable to heavy metal contamination since they often forage over water.

WNS has the potential to be a threat to this species as it has been detected on silver-haired bats, but they have not yet shown diagnostic sign of the disease (White-nose Syndrome.org 2015).

Conservation Measures

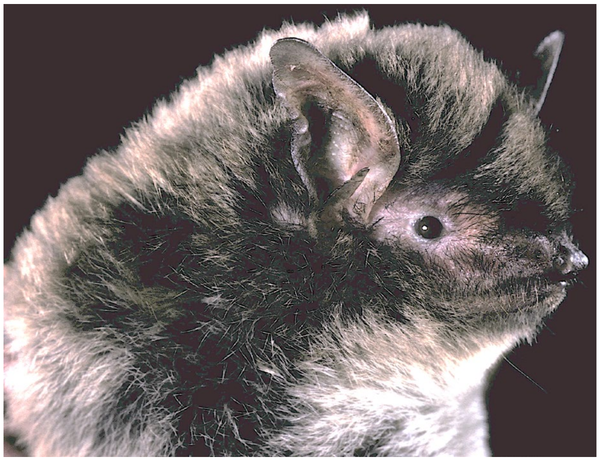
Wind turbines are a relatively new threat, and thus very little research has been conducted on how to minimize the dangers of turbines to bats. What is known is that the new larger, taller turbines have decreased mortality in birds but actually increased bat fatalities (Barclay et al. 2007), and that facilities built on ridge tops appear to have the highest bat fatalities (Johnson and Erickson 2008). Research is greatly needed to identify the best placement of turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). Wind turbine management recommendations for foliage roosting bats from Bunch et al. (2015*c*) include working with wind energy development companies to mitigate the impacts of wind turbines, such as increasing the cut-in speed of turbines to reduce mortalities; and establishing timing and location of potential wind-energy conflicts through pre-construction surveys and determine potential mitigation measures to reduce mortality to silver-haired bats. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Other habitat protection and management recommendations include working to recruit and retain small groups of suitable snags and maintain structural complexity in riparian areas and forest patches (Campbell et al. 1996); provide tall snags in the early stages of decay greater than 2 feet (60 cm) in diameter and exposed to solar radiation (Betts 1996, 1998, Campbell et al. 1996); retain snag density of greater than 21 snags per 2.5 acres (1 hectare) in timber harvest projects (Bunch et al. 2015*a*); and provide snags in open areas greater than 330 feet (100 m) upslope of riparian areas, since they are particularly useful to this species in dry inland forests (Campbell et al. 1996). Other measures may include working to minimize or carefully consider large-scale pesticide use whenever possible; and protect habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*a*) include determining migration routes, timing and patterns of the silver-haired bat; determining where South Carolina's over-wintering population migrates for the summer, perhaps by using stable isotopes from hair or nail samples; studying potential impacts from wind farms and develop strategies to reduce silver-haired bat mortality; determining winter roost site and habitat requirements; determining if silver-haired bats are threatened by pesticide and/or heavy metal contamination; and examining the impacts of winter burns during cold weather on silver-haired bats, particularly on south-facing burn units. The SCDNR Heritage Trust tracks high priority species including the silver-haired bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include creating general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Southeastern Bat (*Myotis austroriparius*)



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Description

The southeastern bat is endemic to bottomland hardwood forests of South Carolina's Coastal Plain, and are rarely far from cypress-gum swamps (Clement and Castleberry 2013*a*) and mature bottomland hardwood forests near lakes and slow moving streams (Cochran 1999, Hoffman 1999, Jones and Manning 1989). One of the unique characteristics of this species is that it's the only North American *Myotis* that normally gives birth to two young instead of one (Rice 1957). It has been hypothesized that because this species has longer periods of annual activity, having two young may be an adaptation to increased exposure to predation (Foster et al. 1978). Population estimates of the southeastern bat are extremely difficult to determine due to its scattered roosting habits and because data is lacking or scarce in many parts of its distribution (Whitaker and Hamilton 1998).

Identification

The southeastern bat is a small to medium sized bat, with females generally larger than females. This species weighs 0.2 to 0.3 ounces (5 to 8 gr) and has a wingspan of 9 to 11 inches (24 to 27 cm) (Harvey et al. 2011). The calcar is unkeeled, the hairs between the toes extend to or past the claws, and the wing membrane attaches at the base of the toe. The tragus is relatively short and rounded compared to other *Myotis* species. The southeastern bat is highly variable in color, with tan or white below and three distinct dorsal pelage color phases including red, gray/brown, and a mixture of the two (Mirowsky 1998). Generally, the pelage is dark at the base with whitish tips, and is thick, wooly, and relatively short. This species resembles the little brown bat (*Myotis lucifugus*), but the little brown bat has conspicuously burnished hair tips, longer, silkier pelage, and does not have whitish tips on its underside.

Taxonomy

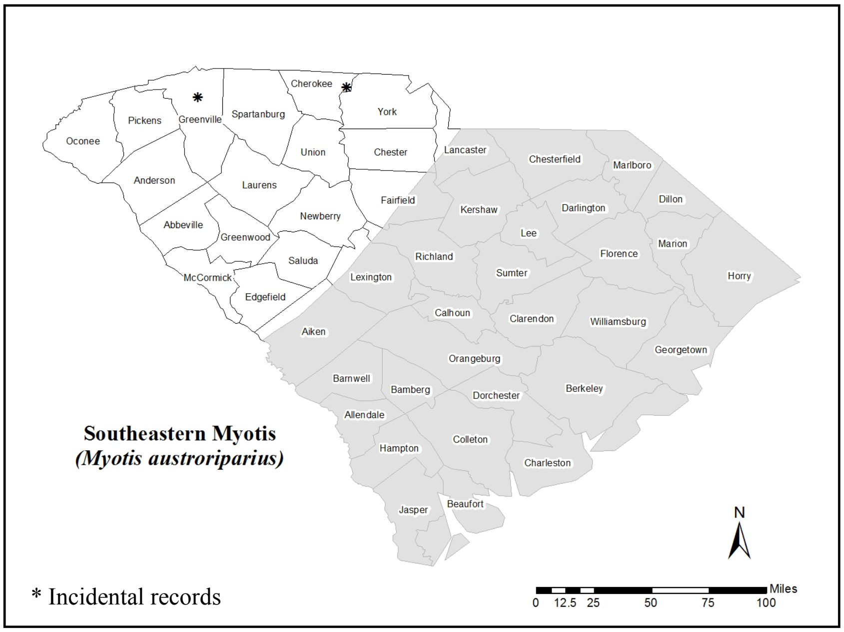
Though this species has been divided into three subspecies in the past, the southeastern bat is now considered monotypic (Wilson and Reeder 2005).

Distribution

Southeastern bats are distributed through the southeastern US from southern Illinois and Indiana in the north, west to southeastern Oklahoma and northeastern Texas, south to northern Florida, and east to southern North Carolina (Hall 1981, Jones and Manning 1989). However, this species has yet to be found in the Piedmont of South Carolina and North Carolina, and is limited to upper and lower Coastal Plain of South Carolina (Fields 2007, Menzel et al. 2003).

Population Status

Though the range of this species covers much of the southeastern US, range-wide population estimates are extremely difficult to determine due to the scattered roosting habits of this species and because data is lacking or scarce in many parts of its distribution (Whitaker and Hamilton 1998). However, it is



known that populations have decreased and this bat is no longer considered common. The southeastern bat has a rank of Globally Apparently Secure (G4), Nationally Apparently Secure (N4), and is Subnationally Critically Imperiled (S1) (NatureServe 2017). It is currently ranked as Subnationally Critically Imperiled (S1S2) by the SCDNR Heritage Trust (see Table 2). It is classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales and Álvarez-Castañeda 2008*f*). The southeastern bat is considered rare in South Carolina and is designated as threatened or "in need of management" (Bunch et al. 2015*b*). This species is a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015)

General Habitat

Permanent sources of water play an important factor in the habitat associated with southeastern bats (Jones and Manning 1989). In the southern coastal plain and lowlands, this species is rarely far from cypress-gum swamps (Clement and Castleberry 2013*a*) and mature bottomland hardwood forests near lakes and slow moving streams (Cochran 1999, Hoffman 1999, Jones and Manning 1989). Common tree species associated with these habitats include black gum (*Nyssa sylvatica*), water tupelo (*N. aquatica*), bald cypress (*Taxodium distichum*), water oak (*Quercus nigra*), willow oak (*Q. phellos*), and swamp chestnut oak (*Q. michauxii*) (Mirowsky and Horner 1997). Southeastern bats have also been found in upland pine forests (Reed 2004), oak-pine and longleaf pine (*P. palustris*) (Schmidly et al. 1977).

Roosts and Roosting Behavior

Southeastern bats have generally been found roosting over water in caves, mines, hollow trees, bridges, buildings, wells, and cisterns (Rice 1957, Lowery 1974, Sealander 1979, Mumford and Whitaker 1982, BCI and SBDN 2013). In the northern and southeastern portion of its range, the preferred sites of this species are caves over water, such as Florida limestone caves where the largest summer colonies roost (Rice 1957, Harvey et al. 1991, Gore and Hovis 1998). Where caves are not available on the Gulf Coast, roosts used include hollow trees, buildings, and other protected sites (Lowery 1974, Foster et al. 1978, Sealander and Heidt 1990).

During summer, southeastern bats have been known to prefer larger trees with larger cavities within 66 feet (20 m) of standing water (Mirowsky 1998). The diameter at breast height (dbh) of roost trees are often large, varying from 30 to 61 inches (76 to 155 cm) (BCI and SBDN 2013). Southeastern bats have used various bottomland hardwood tree species such as large, live, hollow black gum and water tupelo with large basal openings (Cochran 1999, Hoffman 1999, Carver and

Ashley 2008), and sweetgum (*Liquidambar styraciflua*), Nuttall oak (*Q. nuttallii*), water hickory (*Carya aquatica*), water oak, red maple (*Acer rubrum*), and American sycamore (*Platanus occidentalis*) (Reed 2004, Wilf 2004, Stevenson 2008). In South Carolina, live tupelo gum trees within closed canopies were the primary roosting site in the Francis Beidler Forest (Clark et al. 1998). Despite being available, large bald cypress trees were not used as roost sites in Francis Beidler Forest or in areas in Texas, even though they are used as roost sites in Mississippi (Clark et al. 1998, Mirowsky 1998, Stevenson 2008). Roost tree entrances varied in height from 24 to 42 inches (60 to 106 cm) in Texas, Tennessee, and Illinois (Mirowsky 1998, Hofmann et al. 1999, Carver and Ashley 2008).

Maternity colonies are usually composed of around 100 to 300 individuals, though there have been reports of cave colonies that form around mid-March in Florida between 2,000 and 90,000 individuals (Rice 1957, Hoffman et al. 1998, Mirowsky 1998, Hoffman 1999). Maternity colonies are often found in live, mature hollow trees with large basal openings in species such as black gum, water tupelo, American sycamore, sweetgum, Nuttall oak, water hickory, American beech (*Fagus grandifolia*), bald cypress, Pignut hickory (*C. glabra*), swamp chestnut oak (*Q. michauxii*), and overcup oak (*Q. lyrata*) (BCI and SBDN 2013). Maternity colonies have also been found using bridges and culverts (Keeley and Tuttle 1999), cisterns (Sherman 2004), abandoned warehouses (Lee et al. 1982), and an attic in Florida that included up 7,680 southeastern bats and a few thousand Brazilian free-tailed bats (*Tadarida brasiliensis*) (Hermanson and Wilkins 1986). Bridges used include those with concrete arches, concrete flat slabs, and concrete I or T-beams, but do not include those made only of steel or wood (BCI and SBDN 2013), and channel beam bridges where preferred over other bridges in North Carolina (McDonnell 2001). An important factor contributing to roost selection of maternity colonies is consistent warm temperatures and high humidity (Rice 1957, Zinn 1977, Humphrey 1992), which may prevent evaporative water loss in lactating females (Webb et al. 1995). Along with reducing predation, this may explain why many colonies of southeastern bats roost over water (Foster et al. 1978). Nonbreeding females and males don't normally roost in maternity colonies, though males may join once the young are mature (Rice 1957).

Southeastern bats have a variable hibernation strategy, hibernating in the north during winter but staying active year-round in the southern portion of their range (Jones and Manning 1989). During winter in the northern portion of its range, this species is known to hibernate in caves and mines (Rice 1957, Barbour and Davis 1969). This bat may hibernate roosting alone or in groups that include males and females, and can be up to 120 individuals in Indiana, or 3,000 individuals in Kentucky (Barbour and Davis 1969, Hoffmeister 1989, Harvey et al. 1991). Abandoned mines are often used for hibernation roosts in areas where caves are not available, though they may also be used in the vicinity of caves (Smith and Parmalee 1954, Whitaker and Winter 1977). In Arkansas, this species hibernates in drill holes and crevices of abandoned cinnabar mine adits (Reed 2004), but roosts in warmer, more thermally stable mines in the southern end of the state instead of hibernating. Southeastern bats also roost in trees in winter, especially in southern regions. In Florida during winter, this species moves from caves that are too warm to facilitate torpor to exposed roosts in tree hollows, building, culverts, and bridges (Rice 1957, Humphrey 1992). One study found this species may prefer larger trees with larger cavities during winter than spring and summer (Fleming et al. 2013), but otherwise little information is available on winter roost tree characteristics. Southeastern bats are also documented wintering in cisterns (Sherman 2004), culverts (Walker et al. 1996), sheds (Barbour and Davis 1969), a fertilizer plant in Georgia (Davis and Rippy 1968), and in a warehouse in North Carolina that's used as a roost throughout the year (Lee et al. 1982). Overall, very few studies on winter or summer roosting habits of this species have been conducted in South Carolina, though a colony was discovered in a cave system in Orangeburg County which is used as both a summer and winter roost (J. M. Menzel et al. 2003).

Reproduction

Detailed reproductive and mating system information for the southeastern bat is poorly documented. However, mating is thought to occur in the fall in northern populations (Mumford and Whitaker 1982) and in spring in southern populations (Rice 1957, Amelon et al. 2006). Sperm is stored in the female's uterus until spring when fertilization takes place (Lowery 1974). Twins are usually born from April to mid-May (Rice 1957, Jones and Manning 1989), though probably from May to early June in South Carolina (M. A. Menzel et al. 2003). Gestation and lactation periods are unknown, but Rice (1957) reported that young begin to fly at five to six weeks. Also reported was the fact that young are carried by the female the first day after birth, but afterward they tend to form group clusters while the female is away foraging. Both males and females reach sexual maturity within their first year (Rice 1957, Whitaker and Hamilton 1998).

Food Habits and Foraging

Southeastern bats emerge to forage within the first three hours after sunset, and on warmer nights two peaks of foraging activity have been observed (Zinn and Humphrey 1981). This species prefers to forage over water in bald cypress-tupelo gum swamps and bottomland hardwood forests in Illinois, Arkansas, and South Carolina (Clark et al. 1998, Hoffman et al. 1998, Hoffman 1999). They are also found foraging over slow-moving creeks next to upland pine and hardwood forest and narrow beech-magnolia bottoms (Schmidly et al. 1977), in wetlands and mature forested wetlands (Gardner et al. 1992, Horner 1995, Gardner 2008), over water in managed pine forests (Miller 2003), and over livestock ponds (Bain 1981). In dry areas, they are found foraging in live oak habitats, fields, and upland woodlots (Zinn and Humphrey 1981, Humphrey 1992). In the Coastal Plain of South Carolina, southeastern bats are known to forage most actively in Carolina bay wetlands, bottomland hardwood forests and river swamps, and forest gaps, with most activity in stands of trees between 21 to 40 years (M. A. Menzel et al. 2003, Menzel et al. 2005*b*, Ford et al. 2006*a*).

The diet of southeastern bats can be variable (Whitaker and Hamilton 1998), and have been found to consume, in decreasing preference according to Zinn and Humphrey (1981), Diptera, Coleoptera, and Lepidoptera. Specifically, Zinn and Humphrey (1981) found this species selected for mosquitoes and crane flies on cool spring evenings, and Coleoptera, Lepidoptera, and culicid Diptera on warm summer nights when flying insects were diverse. Trichoptera composed a high percentage of this species diet in Illinois (Feldhamer et al. 2009).

The home range of this species is uncertain, but is thought to be between 250 to 1,240 acres (100 to 500 ha) (M. A. Menzel et al. 2003)

Seasonal Movements

Though winter hibernacula and summer maternity sites are generally located in different areas, this species is not considered a long-distance migrant because migration routes have not been documented (Rice 1957, Mumford and Whitaker 1982, Gardner et al. 1992). However, they could be considered a local migrant due to the small seasonal shifts that occur (Clement and Castleberry 2013*b*). For example, in Florida this species disperses from maternity colonies by the end of October and are completely gone by December (Rice 1957). Some banded individuals have been recorded as moving distances of 18 to 45 miles (29 to 72 km) (Rice 1957).

Longevity and Survival

The longest lived individual in the wild for this species has been recorded at 21 years, though the average lifespan may be closer to four to eight years (Nowak 1999). Southern populations may have a lower life span due to higher predation than northern populations (BCI and SBDN 2013). For a stable population not in decline, the annual survival rate has been estimated at 46% (Rice 1957). Young experience a high mortality of 12% for colonies over water (Foster et al. 1978), and 75% of pre-flight mortality has been reported to occur within the first week of life (Hermanson and Wilkins 1986).

Threats

Populations of southeastern bats have been reported as declining dramatically in recent years. For example, in Florida at least 18 maternity caves with around 400,000 adult females were once known, but 1992 surveys found only eight maternity caves with around 200,000 adult females (Gore and Hovis 1992). Species dependent on caves and mines such as the southeastern bat are greatly affected by disturbance during hibernation or maternity periods (Clark et al. 1998, Currie and Carolina 1999), and destruction of these roosts is a leading factor contributing to population declines (Humphrey 1975, Sheffield and Chapman 1992). Examples of human disturbance that have led to abandonment of caves by southeastern bats include vandals, careless cave explorers, blocking caves with rocks, setting guano piles on fire, and turning caves into dump sites (Rice 1957, Mount 1986, Gore and Hovis 1994). Disturbance to hibernacula causes bats to deplete their fat supplies and abandon caves, and disturbance to maternity colonies may lead adults to inadvertently knock young from the roost in their haste to leave, causing juvenile mortality (Foster et al. 1978, Hermanson and Wilkins 1986). Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982). Heavy metals may also be a threat (Bunch et al. 2015*b*), though survival rates in a Florida population were not affected when exposed to high levels of cadmium, lead, chromium, and zinc (Clark 1986).

Flooding has been known to kill 57,000 bats in Florida (Gore and Hovis 1994), and can be exacerbated by land use changes such as impoundments or channelization. Alteration of natural flood regimes may affect the regeneration of important forest community types such as cypress-gum, thus preventing recruitment of future roost trees (Bunch et al. 2015*b*).

Destruction and fragmentation of mature forests in the mountains and Coastal Plain and bottomland hardwood forests of South Carolina is another threat since this species depends on these areas for foraging and roosting (Bunch et al. 2015*b*). In fact, the loss of cypress and tupelo gum swamps, bottom-land hardwood and other forested wetlands has contribute to the decline of southeastern bats (Mirowsky and Horner 1997). Additionally, many of these habitat alterations can cause increased predation by natural predators.

WNS was confirmed in a southeastern bat for the first time in June of 2017 (USFWS 2017*b*). Though more than 90% of bat populations from other species affected by the disease have declined since WNS was first detected, it is unknown how the disease will affect southeastern bats.

Other potential threats cited by Bunch et al. (2015*b*) include abundant invasive exotic vegetation, such as some privet species, that may prevent the regeneration of forest species and impair recruitment of suitable roost trees; genetic isolation of populations and feral cats as unnatural predators at roosts are threats to southeastern bats; and deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) caused by *Phytophthora ramorum*, which was recently detected on nursery stock in South Carolina, even though it has not been found in a natural setting to date.

Another threat to this species is the inadequacy of existing regulations for management of forestry, wind energy development, and oil, gas, and mineral extraction, especially when it comes to the protections afforded a state-listed species. These protections are meant to prevent trade or possession of state-listed species, but do not to protect against habitat destruction (USFWS 2011).

Additionally, small numbers of deadly collisions with towers in Florida have been recorded for this species (Crawford and Baker 1981). However, the level of impact from tower mortalities on either local or range wide populations remains unclear.

Global climate change could be a potential threat because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to southeastern bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and structures that mimic large hollow trees such as large bat towers may be a suitable alternative for southeastern bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to protect mature bottomland hardwood forests and connecting corridors in the Inner and Outer Coastal Plain; recruit younger stages of high quality bottomland habitat for growth into future roost trees; prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides. Also, using flashing lights instead of constant lights on towers, which is now regarded as acceptable by the FAA, can reduce bat mortality (Bunch et al. 2015*a*).

Priority survey and research recommendations from Bunch et al. (2015*b*) include working to determine if prescribed fire represents any threat, and also the acceptable distance of fire, smoke and fire lines from roosts; determine summer and winter roost site requirements; determine the genetic structure of selected colonies and test whether populations are experiencing adverse genetic consequences from isolation and fragmentation; survey and map mines, tunnels, wells and cave-like structures not surveyed in previous efforts; obtain long-term demographic data including reproductive success, sex ratios, survival, immigration and emigration facilitated by dispersal, and determine the effects of biotic and abiotic factors on these parameters; determine if unnatural predation at roosts by feral cats is occurring, including the southeastern bat roost at Orangeburg State Park; develop suitable human-made roosts specific to these species; use existing data on habitat preferences to identify the availability of natural roost habitat and to determine the amount of protected versus unprotected habitat; determine roosting habitat requirements including landscape factors that influence roost habitat quality; obtain basic information on colony size, composition, dynamics, and how these vary with roost site characteristics; identify colonies of southeastern bats and begin long-term monitoring on colony size, persistence, and roost sites; conduct seasonal surveys at caves and mines being considered for closure; evaluate roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the southeastern bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Tricolored Bat (*Perimyotis subflavus*)

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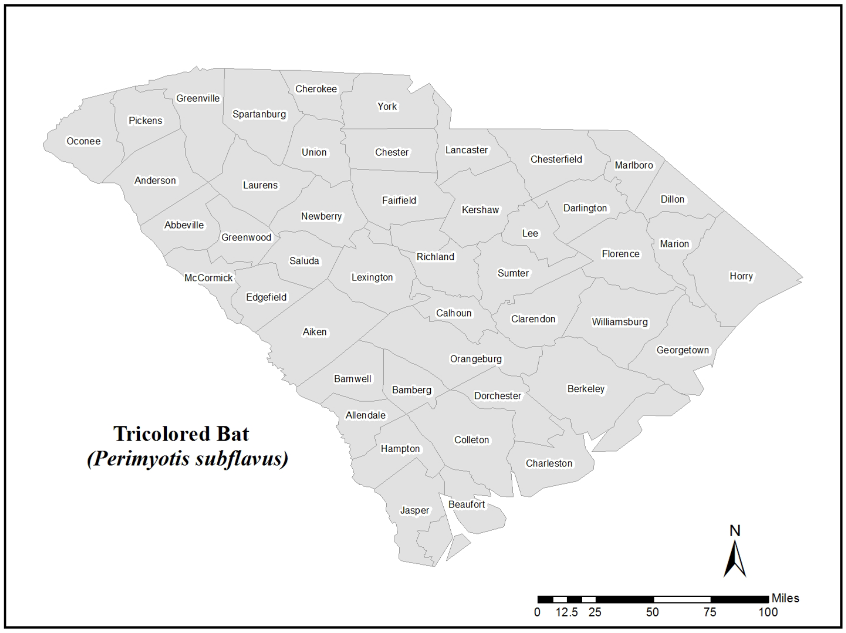
Description
The tricolored bat is a common bat found throughout the forests of the eastern US, and is the second smallest bat found in South Carolina (J. M. Menzel et al. 2003). Before the Genus was changed to *Perimyotis*, it was formerly known as the eastern pipistrelle (*Pipistrellus subflavus*). While hibernating, this species is often found covered in condensation. Unfortunately, populations of tricolored bats have declined greatly due to the effects of WNS since 2006 (Francl et al. 2012, Langwig et al. 2012). The first case of WNS in South Carolina was confirmed on a tricolored bat found at Table Rock State Park in March of 2013. In 2014, two other cases on tricolored bats were confirmed as positive for WNS via histopathology, one of which was discovered at the Stumphouse Mountain Heritage Preserve in Oconee County, and another case in Richland County.

Identification
The tricolored bat is a small bat weighing 0.2 to 0.3 ounces (5 to 8 gr) and has a wingspan of 8 to 10 inches (21 to 26 cm) (Harvey et al. 2011). An obvious identifying characteristic of this species is the pink color of the skin on the radius bone. The term "tricolored" refers to the yellowish-brown pelage whose hairs are dark at the base, yellowish-brown in the middle, and dark at the tips. The calcar is unkeeled, and the base of the underside of the interfemoral membrane is furred. The wing membranes are blackish, but the face and ears have a pinkish color. The tragus is straight, long, and rounded, and the feet are relatively large compared to body size.

Taxonomy
Currently there are four recognized subspecies of the tricolored bat (Wilson and Reeder 2005), and only *Perimyotis subflavus subflavus* occurs in South Carolina (Fujita and Kunz 1984).

Distribution
The tricolored bat is distributed from eastern Canada south through most of the eastern US and into Mexico, and west to Michigan, Minnesota and Texas. Before WNS was detected, the range of this species was expanding westward from South Dakota to Texas and New Mexico (Geluso et al. 2005) and northward into the central Great Lakes region (Kurta et al. 2007). In South Carolina, they are distributed statewide and found in all four physiographic provinces (M. A. Menzel et al. 2003).

Population Status
The tricolored bat has a rounded rank of Globally Imperiled (G2G3), Nationally Vulnerable (N3N4) and Subnationally Unranked (SNR) (NatureServe 2017). However, it is currently ranked as Subnationally Critically Imperiled (S1S2) by the SCDNR Heritage Trust (see Table 2). It is currently classified as Least Concern (LC) on the IUCN Red List (Arroyo-Cabrales et al. 2008*c*). The tricolored bat was considered relatively common throughout the state, however hibernating populations have



recently been affected by WNS and are currently in decline. This species is listed as a Highest Priority species in the South Carolina 2015 SWAP (SCDNR 2015).

General Habitat

Tricolored bats are associated with forested landscapes, often in open woods and found over water and adjacent to water edges (Fujita and Kunz 1984, Schmidly 1991, Nowak 1999). In South Carolina, sparse vegetation and early successional stands were found to be the best predictor of foraging habitat use by tricolored bats (Loeb and O'Keefe 2006).

Roosts and Roosting Behavior

Summer maternity roosts and winter hibernacula are usually located in different areas (Amelon 2006). During summer, this species is known to use caves, rock crevices, tree foliage, Spanish moss and buildings as roosts (Schmidly 1991, Menzel et al. 1999*a*, Nowak 1999, Briggler and Prather 2003). More than one roost location may be used by summer roosting groups (Whitaker and Hamilton 1998), and individuals roosting in buildings are known to commonly switch roosts (Ammerman et al. 2012). Additionally, caves with high humidity may be chosen as a summer roost by both males and females in arid regions (Caire et al. 1984). In South Carolina, this species has been found in the cavities of bottomland hardwood tree species such as swamp chestnut oak (*Quercus michauxii*), sweetgum, and laurel oak (*Q. laurifolia*) (Carter et al. 1999), as well as in Spanish moss in understory trees on exposed high-marsh hammocks (Menzel et al. 1999*a*). A colony was also found in the attic of a garage in Oconee County (Golley 1966). Evidence of tricolored bats in the southern Appalachian Mountains indicated that they preferred roosts near streams (O'Keefe et al. 2009).

Maternity roosts are found in human-made structures such as houses and barns (Allen 1921, Poole 1938, Lane 1946), ammunition storage bunkers (Jones and Pagels 1968, Jones and Suttkus 1973), and road culverts (Sandel et al. 2001), but may also include trees (Humphrey 1975), caves (Humphrey et al. 1976), rock crevices (Barbour and Davis 1969, Fujita and Kunz 1984), and even squirrel nests (Veilleux et al. 2003). Veilleux et al. (2003) found that 19 reproductive tricolored bats in Indiana preferred oaks as roost trees, and roosted exclusively in foliage, with 65% in clusters of dead leaves, 30% in live foliage, and 5% in squirrel nests. In this study, they also found the mean roost tree height to be around 68 feet (20.8 m), the roost height from the ground to be 52 feet (15.7 m), and the roost tree diameter at breast height to be 13 inches (33.2 cm). Females roost in maternity colonies with an average of 15 individuals, or up to 50 (Perry and Thill

2007*c*), and some observations suggest roost switching may be common during the maternity period (Whitaker and Hamilton 1998). Reproductive tricolored bats have been known to stay at roost trees for an average of six days before travelling between 62 to 456 feet (19 and 139 m) to another roost site carrying their young (Nowak 1999, Veilleux et al. 2003). The mean maximum distance moved between roost locations for this species in the southern Appalachian Mountains was 1,968 ± 738 feet with a range of 46.9 to 5, 964.2 feet (600 ± 225 m; range 14.3–1817.9 m) (O'Keefe 2009). However, some evidence from reproductive females in Indiana suggests that this species may have site fidelity to small roost areas within and between years (Veilleux and Veilleux 2004).

Like the eastern red bat, tricolored female bats may have higher temperature demands for birthing and nursery conditions and be restricted to lower elevations associated with higher temperatures during summer in the eastern US (Ford et al. 2002). During periods of low temperatures, females may enter torpor and reduce milk and energy output to the pups, which may contribute to reduced growth rates (Hoying and Kunz 1998). Males roost alone during the summer (Whitaker and Hamilton 1998), and fidelity to roost sites is relatively high as evidenced by the fact that they have been recorded as using the same foliage roost for up to 33 days (Whitaker and Hamilton 1998, Perry and Thill 2007*c*). In South Carolina, basal cavities may serve as maternity roosts for tricolored bats (Menzel et al. 1996). In South Carolina and Indiana, females form maternity colonies of three to five individuals in clusters of live or dead leaves in trees (Bunch et al. 2015*b*). Males in North Carolina are known to use large diameter oaks and hickories for roosts, and use trees taller than the nearest tree but not necessarily the tallest tree in the plot area (O'Keefe et al. 2009, Bunch et al. 2015*b*).

During winter, tricolored bats are obligate hibernators even when food is available in warmer climates (Briggler and Prather 2003), and they rarely leave hibernacula during this time (Whitaker and Rissler 1992*b*). Hibernacula include highway culverts (Walker et al. 1996, Sandel et al. 2001), tunnels (Mohr 1942), storm sewers (Goehring 1954), caves (Hahn 1908, Swanson and Evans 1936, Davis 1966, Raesly and Gates 1987) and mines (Sealander and Heidt 1990, Whitaker and Rissler 1992*b*, Menzel et al. 1997). This species may be one of the earliest bats to arrive to hibernacula and the last to leave (LaVal and LaVal 1980), and bats tend to stay in deep torpor for longer periods of time (maximum recorded at 11 days, (Twente et al. 1985)) than other temperate hibernating bats between arousals from hibernation (Amelon 2006). Beginning in late July through October, males and females may roost in the same hibernacula, generally hibernating singly, and disperse again in early April (Griffin 1940, Fujita and Kunz 1984, Schmidly 1991). Factors that contribute to the selection of hibernacula include east-facing openings and the distance and abundance of the nearest forest available (Sandel et al. 2001, Briggler and Prather 2003), as well as standing water and mine entrance size and gradient (Menzel et al. 1999*a*). Tricolored bats also frequently use locations deep within hibernacula where temperatures are stable, humidity is high, and airflow is minimal (Hitchcock 1949, Rabinowitz 1981, Caire et al. 1989). Site fidelity to hibernacula for this species is relatively high, at 30 to 60% (Hahn 1908, Menzel et al. 1999*a*). Night roosts include caves, mines, and rock crevices (Barbour and Davis 1969). In South Carolina, tricolored bats are consistently found in abandoned mines and incomplete Blue Ridge Railroad tunnels in the mountains during winter hibernacula surveys (Bunch et al. 2015*b*). Golley (1966) reported a tricolored bat roosting under a house in Berkeley

County, as well as a large colony roosting in caves in Orangeburg County. However, there have been no studies quantitatively examining winter roosting habits for this species in the state.

Reproduction

Mating occurs between August and October and again during ovulation in spring, and sperm is stored in the female's uterus until spring when fertilization takes place (Guthrie 1933, Whitaker and Hamilton 1998). Twins are usually born from June to mid-July in northern portions of this species range, and May through June in the southern portions (Fujita and Kunz 1984, NatureServe 2017). Gestation lasts 44 days (Wimsatt 1945), young begin to fly at three weeks (Lane 1946, Hoying 1983), and are weaned at four weeks (Whitaker and Hamilton 1998). Depending on environmental conditions, sexual maturity may be attained between 3 and 15 months (Krutzsch and Crichton 1986, Hoying and Kunz 1998).

Food Habits and Foraging

The tricolored bat is one of the earliest bats to emerge at night (Fujita and Kunz 1984), and is thought to feed until midnight and again near dawn (Amelon 2006). This species has a relatively slow, erratic flight pattern, low wing loading, and a higher aspect ratio that reflect their longer, more pointed wings (Farney and Fleharty 1969, Paradiso 1969, Hoying and Kunz 1998). Tricolored bats are considered a clutter-adapted species, but are also well adapted to foraging in open habitats, canopy gaps, edge habitats, and along waterways of forest edges (Barbour and Davis 1969, Fujita and Kunz 1984, Veilleux et al. 2003). This species has been recorded feeding over the top of streamside vegetation and taller streamside trees (Caire et al. 1984, Harvey et al. 1999*a*), however, their activity did not differ above, within, or below the forest canopy in a South Carolina study by Menzel et al. (2005). Tricolored bats appeared to primarily use areas of unfragmented forest cover in Nova Scotia (Farrow and Broders 2011). Most foraging activity tends to occur in riparian areas, as seen in studies in Georgia (Ellis et al. 2002), South Carolina (Menzel et al. 2005*b*), and an Appalachian forest in West Virginia (Ford et al. 2005). Bottomland hardwoods and pine stands have been reported as foraging areas at the Savannah River Site in South Carolina (Carter et al. 1999), and at the same study location Menzel et al. (2003*b*) reported the greatest activity around lakes and ponds, bottomland hardwood forests, and grass-brush habitats. In forest stands of different ages, Menzel et al. (2003*b*) recorded the most activity in clearcuts, (as well as roads and open water habitats) with moderate activity in stands four to 20 years old. However, tricolored bats in the southern Appalachian Mountains only used stands greater than or equal to 72 years in age at an average elevation of 2,893 feet (882 m) (O'Keefe et al. 2009). In relation to fire treatments in South Carolina, Loeb and Waldrop (2008) found the activity of tricolored bats did not vary significantly between thinned, burned, or the control tree stands. Some female tricolored bats in Indiana have been found foraging up to 2.6 miles (4.2 km) away from roost locations (Veilleux et al. 2003), while the distance traveled from roosting areas to foraging locations in Georgia averaged 0.7 miles (1,137 m) (Krishon et al. 1997). In South Carolina, the activity of tricolored bats has been recorded widely around Lake Jocassee and Lake Keowee, in April, July and October at all of the 31 sites surveyed (Webster 2013).

Considered a generalist insectivore, the tricolored bat consumes Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, and Trichoptera ranging in size from 0.16 to 0.4 inches (4 to 10 mm) in length (Whitaker 1972, Griffith and Gates

1985, Brack Jr. and Finni 1987, Carter et al. 2003). Compared to the relative availability of prey in a study in Georgia, lepidopterans where preferred while coleopterans and homopterans were selected for less than what might be expected based on availability (Carter et al. 1998).

The home range of tricolored bats has been reported as 961 acres (389 ha) in Georgia, and 978 acres (396 ha) in South Carolina (Krishon et al. 1997, Carter et al. 1999). The habitats within the home range in Georgia were comprised of 47% high-marsh, 24% oak (*Quercus* species), and 17% loblolly-slash pine (*Pinus taeda, Pinus elliottii*) (Krishon et al. 1997).

Seasonal Movements

The tricolored bat is known to be a latitudinal and regional migrant as well as a long-distance migrant in northern populations (Fraser et al. 2012, NatureServe 2017). Banded individuals have been reported as making regional migrations up to 85 miles (136 km) (Griffin 1940, Barbour and Davis 1969). In the southern portion of its range, males have been shown to have a southern fall migration (Fraser et al. 2012). Populations in the mountains of South Carolina may migrate, but otherwise tricolored bats are thought to be resident to the state.

Longevity and Survival

The oldest tricolored bat was recorded at nearly 15 years old, though the lifespan of this species in the wild is four to eight years (Walley and Jarvis 1971, Whitaker and Hamilton 1998, Nowak 1999). High mortality has been reported to occur between the first and second hibernation period, and for juveniles is especially high during the second summer (Davis and Hitchcock 1965, Davis 1966). Survival rates have been reported as being higher in males than females (Amelon 2006).

Threats

WNS is a major threat to tricolored bats because populations of this species have already declined greatly since 2006 due to its effects (Francl et al. 2012, Langwig et al. 2012).

Disturbance or destruction of natural and artificial roost structures pose additional major threats to this species, especially to hibernacula and maternity roosts (Amelon 2006). Many forms of habitat alteration can also cause increased predation by natBural predators (Bunch et al. 2015*b*).

Wind turbines pose a threat to tricolored bats, especially if erected near roosts, colony sites, and along migratory pathways, as mortalities have been reported at multiple wind-energy facilities in the US (Ellison 2012). This species is frequently killed by wind turbines, and deaths may account for up to 25% of total bat deaths (Arnett et al. 2008). For example, tricolored bats where one of six bat species killed at a wind power development at Buffalo Ridge, Minnesota (Johnson et al. 2003), and were one of the top three species with the highest total mortality at the Buffalo Mountain Windfarm in Tennessee (Fiedler 2004). No wind turbines have been placed in South Carolina to date, however, Clemson University is constructing a test facility for turbines at the coast (Bunch et al. 2015*b*).

Pesticide poisoning, especially by organochlorines and anticholinestrase, is a threat to this species because it has been shown to cause population declines in insectivorous bats (Geluso et al. 1976, Reidinger 1976, Brady et al. 1982). Pesticides can also alter behavior, cause mortality, and be transferred to nursing young (Clark 1981, 1986, Henny et al. 1982).

Deforestation of oak (*Quercus* species) from Sudden Oak Death (SOD) disease caused by the plant pathogen *Phytophthora ramorum* may pose a threat to habitats critical to forest-dwelling bats. Though it has not been found in a natural setting to date, this disease was recently detected on nursery stock in South Carolina (Bunch et al. 2015*b*)

Global climate change is a potential threat to tricolored bats because it may make southern hibernation sites unsuitable due to increased temperatures (Bunch et al. 2015*b*).

Conservation Measures

State law protects all bat species in South Carolina, and thus extermination isn't an acceptable option of bat control. Sealing out bats and/or adding more light to the roost of a colony are more effective alternatives than use of pesticides for control purposes (Laidlaw and Fenton 1971, Barclay et al. 1980). To minimize negative impacts to tricolored bats, eviction from buildings should include appropriately timed exclusion methods. To avoid the maternity period, bats should not be evicted from May through July. Alternatively, populations at the roost area may be decreased by 41 to 96% if lights are introduced to the area (Laidlaw and Fenton 1971). Measures should be taken to provide species-specific alternate roost structures before eviction, and typical bat boxes may be a reasonable alternative for tricolored bats.

Other habitat protection and management recommendations from Bunch et al. (2015*b*) include working to prevent or reduce disturbance to natural and artificial roost structures, as well as to maternity colonies and hibernacula through gating, warning or interpretive signs, prevention of trails or roads to these sites, and other protective measures; retain and recruit cypress-gum swamp forests with large cavity trees; designate no-cut buffer zones around known roosts; provide forested corridors between harvested units; and protect foraging areas and migration corridors, which could be done through landowner incentive programs, conservation easements, lease agreements, or purchases. Other measures may include providing, protecting, and maintaining large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas; attempting to create or maintain patches of structurally diverse forest in order to provide a wide variety of suitable roosting and maternity sites; minimizing large-scale pesticide use whenever possible; and protecting habitat above or around maternity roosts and known foraging areas from pesticides.

Priority survey and research recommendations from Bunch et al. (2015*b*) include conducting seasonal surveys at caves and mines being considered for closure; and evaluating roost and appropriate food (insects high in polyunsaturated fats) availability, as well as roost temperatures, and compare these factors with winter survival. Further research is greatly needed to identify the best placement of wind turbines, as well as strategies that would minimize impacts to bats (Ellison 2012). The SCDNR Heritage Trust tracks high priority species including the tricolored bat, and researchers are requested to submit bat data and occurrence records to their database.

Education and outreach goals recommended by Bunch et al. (2015*b*) include working to create general public and environmental education programs focusing on this bat species to stress the importance of preventing bat population declines, including the development of brochures, interactive websites and study plans.

Chapter 4: Conservation Actions and Strategy

Typically, bat conservation and research has focused on easily surveyable populations of species that aggregate in large numbers, such as big brown bats and tricolored bats. However, very little is known about bat species that roost singly, which include all the foliage roosting species in South Carolina, or species that tend to roost in small groups in difficult to survey areas, such as two of the highest priority species in the state: the threatened northern long-eared bat and the eastern small-footed bat. One of the largest requirements needed for the success of this conservation plan is complete and reliable information on abundance, distribution, demography, life history, and habitat needs for most of South Carolina's bat species. Without much of this basic ecological data, habitat protection plans and land management strategies cannot be fully informed, and can therefore only contribute limited benefits toward bat conservation. One of the most well known threats to bats over time has been the loss or degradation of important roosting and foraging habitat, so conservation efforts that seek to protect species habitat associations may be most successful. A current emerging threat to bats in the state is WNS, and a continued commitment to decontamination protocols as well as more research on how exposure to *Pd* may affect certain species is needed. Other major threats that need to be addressed include human disturbance, environmental contaminants, wind energy development, unknown impacts of agriculture and forest management practices, and potential environmental changes associated with climate change. Lastly, partnerships and cooperation between government agencies, private landowners, non-governmental organizations, and the public are essential if the state is to accomplish its bat conservation objectives.

This chapter addresses these concerns with both short and long-term goals, including specific tasks that seek to conserve populations of South Carolina's bat species. Much of the conservation actions combined and organized here come directly from the Colonial Cavity Roosting Bats Guild, Foliage Roosting Bats Guild, and Silver-haired Bat Supplemental Volumes in the South Carolina SWAP (SCDNR 2015), as well as The Conservation Strategy for Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*) and Southeastern Myotis (*Myotis austroriparius*) (BCI and SBDN 2013). These peer-reviewed recommendations include pertinent information for monitoring, education, public outreach, cooperative efforts, and priority research and survey needs that help guide specific conservation and management actions for South Carolina's bats.

CONSERVATION OBJECTIVES

1. Develop Specific Action Plans
2. Continue Baseline Population Inventory and Monitoring
3. Maintain and/or Contribute to a Bat Database
4. Protect and Provide Specific Roost Sites
5. Monitor and Mitigate Emerging Threats
6. Identify, Protect, and Enhance Bat Habitat and Drinking Resources
7. Conduct Necessary Research
8. Provide Education, Extension, and Outreach
9. Partner with Agencies, Landowners, and Other Groups
10. Integrate and Maintain the South Carolina Bat Conservation Plan

1. Develop Specific Action Plans

1.1. Identify Species and Habitats of High Priority

Twelve of the 14 bat species in South Carolina are “Species of Greatest Conservation Need” and “Highest Priority” in the SWAP (SCDNR 2015), and include those listed as threatened or endangered either federally or at the state level (refer back to Table 2). These species are the federally threatened northern long-eared bat, the state endangered Rafinesque’s big-eared bat, the state threatened eastern small-footed bat, and the big brown bat, hoary bat, little brown bat, northern yellow bat, eastern red bat, Seminole bat, silver-haired bat, southeastern bat, and tricolored bat. Only two of South Carolina’s bat species are not considered priority, the Brazilian free-tailed bat and evening bat. Habitats of high priority have been delineated in the SWAP, and are defined as any habitat type optimally suited for one or more priority species. The habitat types utilized by the highest priority bat species are shown in Table 6. The greatest number of threatened and endangered species fall under four habitat types in the Blue Ridge ecoregion and are Appalachian oak forest, high elevation forest, low elevation acidic

Table 6: Terrestrial priority species and their ecosystems. Modified from Appendix 1-A in SWAP (SCDNR 2015). Bat species highlighted in gray are endangered or threatened either federally or on the state level.

	BLUE RIDGE ECOREGION									PIEDMONT ECOREGION								SANDHILLS ECOREGION								
COMMON NAME	Appalachian Oak Forest	High Elevation Forest	Low Elevation Basic Mesic Forest	Low Elevation Acidic Mesic Forest	Rock Outcrops	Bottomlands and Riparian Zones	Depressions	Wet/Moist Unique Landforms	Grasslands/Early-Successional	Upland Pine Forest	Mesic Forest	Rock Outcrops	River Bottoms	Piedmont Small Stream Forest	Cove Forest	Depressions	Grasslands/Early-Successional	Sandhills Pine Woodlands	Mesic Forest	Rock Outcrops	Blackwater Stream Systems	River Bottoms	Depressions	Seepage Slopes	Upland Mixed Forest	Grasslands/Early-Successional
Big Brown Bat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Eastern Red Bat	1	1	1	1		1	1			1	1		1	1	1	1		1	1		1	1	1	1	1	
Eastern Small-footed Bat	1	1	1	1	1	1	1																			
Hoary Bat	1	1	1	1		1	1	1		1	1		1	1	1	1		1	1		1	1	1	1	1	
Little Brown Bat	1	1	1	1	1	1	1																			
Northern Long-eared Bat	1	1	1	1	1	1	1																			
Northern Yellow Bat																						1				
Rafinesque’s Big-eared Bat	1	1	1	1	1																1	1	1	1		
Seminole Bat										1	1			1		1		1	1		1	1	1		1	
Silver-haired Bat	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1						1	
Southeastern Bat																			1		1	1	1		1	
Tri-colored Bat	1	1	1	1	1	1	1			1	1	1	1	1	1			1	1	1	1	1	1		1	
Total Species	*9*	*9*	*9*	*9*	*7*	*8*	*8*	*3*	*2*	*6*	*6*	*2*	*5*	*6*	*5*	*5*	*1*	*6*	*7*	*2*	*7*	*8*	*7*	*4*	*7*	*1*

Table 6 (cont): Terrestrial priority species and their ecosystems.

COMMON NAME	COASTAL PLAIN ECOREGION: Pine Woodland	Sandhill Pine Woodland	Mesic Forest	Carolina Bays	Hardwood Slopes & Stream Bottoms	Blackwater Stream Systems	River Bottoms	Depressions	Upland Mixed Forest	Maritime Forest	Grasslands/Early-Successional	COASTAL ZONE ECOREGION: Pine Woodland	Mesic Forest	Hardwood Slopes & Stream Bottoms	Blackwater Stream Systems	River Bottoms	Depressions	Hammock Islands	Maritime Forest	Upland Mixed Forest	Marine	Man-Made Structures
Big Brown Bat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1		1
Eastern Red Bat	1	1	1	1	1	1	1		1	1		1	1	1					1	1		
Eastern Small-footed Bat																						
Hoary Bat	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		
Little Brown Bat																						
Northern Long-eared Bat												1								1		
Northern Yellow Bat	1	1	1		1		1	1	1	1		1	1	1		1	1		1	1		
Rafinesque's Big-eared Bat	1		1		1	1	1	1	1						1	1	1					1
Seminole Bat	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1		
Silver-haired Bat	1	1	1							1		1	1	1					1	1		
Southeastern Bat			1	1	1	1	1	1	1	1			1	1	1	1	1		1	1		1
Tri-colored Bat	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	
Total Species	*8*	*7*	*9*	*6*	*8*	*7*	*8*	*7*	*8*	*7*	*1*	*8*	*8*	*8*	*6*	*6*	*6*	*3*	*8*	*9*	*1*	*3*

*1's for Northern long-eared bat are an upcoming update to the SWAP that have not yet been incorporated.

Modified from Appendix 1-A in SWAP (SCDNR 2015). Bat species highlighted in gray are endangered or threatened either federally or on the state level.

mesic forest, and low elevation basic mesic forest; and one habitat type in the Coastal Plain, mesic forest. These habitats are not only used by the largest number of bat species, but also by those that are threatened and endangered either federally or on the state level. Other habitats utilized by over half of the state's highest priority bat species include bottomlands and riparian zones, depressions, hardwood slopes and stream bottoms, maritime forest, pine woodland, river bottoms, upland mixed forest, blackwater stream systems, rock outcrops and sandhill pine woodland. Within these habitats are specific habitat requirements for high priority bat species used during various stages of their life cycle, and the SWAP also briefly outlines these more commonly used sites (Table 7).

Table 7: Specific habitat requirements for highest priority bat species. Modified from Appendix 1-A in SWAP (SCDNR 2015). Bat species highlighted in gray are endangered or threatened either federally or on the state level.

COMMON NAME	SPECIFIC HABITAT REQUIREMENTS
Big Brown Bat	Buildings, cavity trees, under bridges and in bat boxes; forage in open fields or forest gaps
Eastern Red Bat	Thinned stands; roost on smaller branches or twigs, often in the hardwood tree canopy; may roost in leaf litter
Eastern Small-footed Bat	Caves, mines, abandoned buildings, rock crevices and shelters, and crevices within bridges in wooded areas
Hoary Bat	Tree cavities, trunks, tree foliage, squirrel nests, and Spanish moss
Little Brown Bat	Buildings and picnic shelters, cavity trees, caves
Northern Long-eared Bat	Crevices and cavities in dead or live-damaged trees, but they sometimes roost between loose bark and the bole of dead trees; forage in mature stands
Northern Yellow Bat	Forage over open areas such as fields, pastures, golf courses, marshes, and along lake and forest edges; roost in clumps of Spanish moss or under old palm fronds
Rafinesque's Big-eared Bat	T-beam and I-beam bridges, abandoned buildings, old bunkers and tunnels, cavity trees, rock outcrops, mines, caves
Seminole Bat	Roost in large pines located near forested corridors; may roost in leaf litter
Silver-haired Bat	Roosts include tree cavities, under loose bark, rock crevices, under tree foliage, and occasionally in buildings, stacks of firewood, and bird boxes; forage over water
Southeastern Bat	Caves (including limestone sinks), mines, abandoned buildings, and large hollow trees; prefers to feed and roost over water
Tri-colored Bat	Abandoned mines and caves, bridges, buildings

1.2. Determine Lead Agencies and Potential Funding Sources

1.2.1. Lead agencies could include:

- South Carolina Department of Natural Resources (SCDNR)
- South Carolina Department of Parks, Recreation, and Tourism (SCPRT)
- South Carolina Forestry Commission (SCFC)
- United States Forest Service (USFS)
- United States Fish and Wildlife Service (USFWS)
- National Wildlife Refuge System (NWRS)
- National Park Service (NPS)
- South Carolina Universities
    - Clemson University, Furman University, Lander University, South Carolina Upstate, Southern Wesleyan University, University of South Carolina, etc.

1.2.2. Potential funding sources could include:

- State Wildlife Grant Program - provides federal grant funds for developing and implementing programs that benefit wildlife and their habitats (including species not hunted or fished) with priority for projects benefitting species of greatest conservation need.
- Wildlife Restoration Program - provides grant funds to the states and insular areas fish and wildlife agencies for projects to restore, conserve, manage and enhance wild birds and mammals and their habitat.
- SC Forest Legacy Program - a habitat protection program that contributes funding for high conservation value land purchases.
- Farm Bill Programs - may contribute funding on cultivated and pasture land for conversion to native vegetation, which could benefit bats by providing higher quality foraging habitat.

1.2.3. Other potential funding could come from environmental organizations such as:

- South Carolina Wildlife Federation (SCWF)
- The Nature Conservancy (TNC)
- The Wildlife Society (TWS)
- National Fish and Wildlife Foundation (NFWF)
- National Wildlife Federation (NWF)
- Bat Conservation International (BCI)

2. Continue Baseline Population Inventory and Monitoring

In addition to other conservation actions outlined, it is important to continue to allocate effort and funds toward ongoing long-term inventory and monitoring projects.

2.1. Caves and Mines

- Continue full and follow-up counts at Stumphouse Tunnel hibernacula (SCDNR 2018).
- Continue entrance or emergence counts at Santee State Park when partners are available (SCDNR 2018).
- Continue monitoring of other hibernacula where access is permitted at sites without a vertical component on a rotation of three to five years or more (SCDNR 2015, 2018).

2.2. Buildings and Bridges

- Continue monitoring, netting, and sampling of the little brown bat maternity colony at the SCDNR Walhalla Fish Hatchery in Oconee County (SCDNR 2015).
- Continue long-term monitoring of bridges in the Coastal Plain for Rafinesque's big-eared bats (SCDNR 2015).

2.3. Other Roosting Areas

- Continue and/or increase infrared (IR) video photography monitoring of some known roosts to detect dramatic declines in bat populations (SCDNR 2018).

- Continue long-term monitoring of Rafinesque's big-eared and other known bat roosts in the Blue Ridge and Piedmont ecoregions (SCDNR 2015).

2.4. Acoustic Surveys

- Continue survey routes in Carolina Sandhills National Wildlife Refuge and Francis Marion National Forest (SCDNR 2015, 2018).
- Continue survey route at Long Cane Ranger District (SCDNR 2015, 2018).
- Continue NABat acoustic surveys established statewide to monitor bat occupancy rates on a seasonal and annual basis. The first year of sampling was completed in 2015, and will be conducted annually each summer (SCDNR 2015, 2018).

3. Maintain and/or Contribute to a Bat Database

A main component of monitoring and research is maintaining capture and location information for all of South Carolina's bat species. This way data can be more readily analyzed and shared with cooperators.

3.1. Heritage Trust Database and the USGS Bat Population Database

- Continue maintaining and contributing to the Heritage Trust Database. The SCDNR Heritage Trust tracks high priority species, and researchers are requested to submit bat data and occurrence records to their database. The Heritage Trust periodically provides data to the USGS Bat Population Database (BPD), a multi-phase, comprehensive effort to compile existing population information for bats in the US and Territories at https://my.usgs.gov/bpd/.

4. Protect and Provide Specific Roost Sites

South Carolina's bat species utilize a wide variety of roosting locations for processes their populations depend on to survive, such as caves and mines for hibernation and hollow trees or human made structures for maternity colonies. To address protecting bats from disturbance at roost sites, SCDNR has partnered with several parks in the state. In general, implementation of signs, gates, and fences help to protect existing roost sites.

4.1. Protect Existing Roost Sites

4.1.1. Caves and Mines

- Construct a fence around the southeastern bat colony at Orangeburg State Park and find a way to maintain it.
- Control human access to important mines, caves, and rock shelter formations by signage or other restrictions such as road closures, and do not create trails or roads to these sites (BCI and SBDN 2013, SCDNR 2015).
- Do not seal off, alter, or destroy cave, karst, and other subterranean roosts (BCI and SBDN 2013).
- Close subterranean hibernacula to recreational activities to avoid waking

hibernating bats or disturbing maternity colonies (BCI and SBDN 2013).

- Gate and construct fences around underground entrances to enhance human safety and reduce landowner liability (BCI and SBDN 2013).
  - Install bat friendly and custom fit cave and mine gates on site with horizontal steel bars that allow bat access yet control human access through locked entrances, whenever financially feasible. To allow bats in and out of the cave, spacing between bars should be 5 3⁄4 inch (14.6 cm). For larger bat colonies that may be restricted by standard gate rails, consider gate designs that incorporate windows, chutes, and flyover options (Powers 2004, Kennedy 2006). Avoid fences at distances within 16 feet (5 m) of an entrance. Sufficient distances are generally over 50 feet (15 m). The most effective fences for deterring trespassers are those over 10 feet (3 m) high made of no-climb chain link or other small-mesh, and include a smooth top wire angled away from the entrance (Ludlow and Gore 2000). Smooth wire instead of barbed wire prevents bats from becoming entangled closer to the entrance, though barbed wire will help deter trespassers if the fence is far from the entrance (BCI and SBDN 2013).
- Designate a habitat buffer zone of at least ¼ mile (400 m) around priority cave and mine roosts (BCI and SBDN 2013). Larger buffer zones may be needed for species such as Rafinesque's big-eared bats and southeastern bats, but more research is needed to evaluate this (Clark 1990, Hurst and Lacki 1999).

4.1.2. Snags and Trees

- Collect GPS coordinates and mark maternal roost trees for re-identification to assist in land management so that tree roosts that are buffered from disturbances such as the removal of neighboring trees, creation of roads and trails at or near the roost site, and other changes in the surrounding habitat. Doing so will help to avoid changes in roost microclimate or alter roosting conditions that may change tree suitability for bats (BCI and SBDN 2013).
- Designate buffers (no-cut zones) around known roosts to avoid altering microclimate roosting conditions and the suitability of trees for bats (BCI and SBDN 2013, SCDNR 2015).
- In timber harvest projects, retain a snag density of >21 snags/hectare for silver-haired bats, as well as for northern long-eared bats and evening bats (SCDNR 2015).
- Retain Spanish moss and old palm fronds on public lands to benefit northern yellow bats (SCDNR 2015).
- Encourage retention of Spanish moss and old palm fronds on private lands to benefit northern yellow bats (SCDNR 2015).
- Provide, protect, and maintain large diameter roost trees, large snags, decadent trees, hollow trees, and roost structures, especially near water or riparian areas (BCI and SBDN 2013, SCDNR 2015).

- Provide suitable roost sites for northern long-eared bats, which include live trees and/or snags greater than 3 inches dbh with exfoliating bark, cracks, crevices, and/or cavities (USFWS 2015*b*).
- Use active management at selected sites to inhibit understory or mid-story development to provide access for bats to roost trees (BCI and SBDN 2013).
- Species of trees that produce basal cavities such as bald cypress, sycamore, sweet gum, water tupelo, tulip poplar, and black gum where bats use these tree hollows as roosts should be encouraged in forest management. This can be done by allowing younger, developing trees of these species to mature and promote recruitment of future roost trees (BCI and SBDN 2013).

4.1.3. Buildings and Bridges

- Repair structures to protect bat roosts and ensure longevity. If this is not possible, measures should be taken to provide alternate roost structures at each significant site before the structure is taken down or altered in a way that renders it no longer beneficial to bats (see section 4.2 for species-specific roost structures) (SCDNR 2015).
- Collaborate with the South Carolina Department of Transportation (SCDOT) to protect bat roosts and habitats during and after road construction, bridge replacement, and bridge maintenance (BCI and SBDN 2013, SCDNR 2015). Specific guidelines exist for bridge design and maintenance for sites with bat roosts, and planning should begin at least a full year prior to replacement (BCI and SBDN 2013).

  Currently, the SCDOT receives a copy of the SCDNR's Heritage Trust Threatened and Endangered Species database on an annual basis for use in planning purposes. They are also encouraged to report bat colonies on bridges so that mitigation efforts can be made if the bridge needs to be modified or replaced. For example, at the Stevens Creek bridge by the SCDNR Heritage Preserve, a replacement will be constructed that will be I-beam or T-beam instead of slab to benefit bats. Some of this work is handled though discussions with environmental consultants working on bridge projects with wetlands impacts. However, SCDNR needs to create a Memorandum of Understanding (MOU) with SCDOT that covers voluntary guidelines for assessing bat use, conservation actions, and bridge replacement strategies (BCI and SBDN 2013, SCDNR 2015). For example, it's been suggested that alternate roosts become a standard part of bridge replacement requests from the SCDNR (SCDNR 2015). Other suggestions might include:

  – Create adaptations to new, long bridges over water in the Sandhills and Inner and Outer Coastal Plain (SCDNR 2015).
  – If a structure similar enough in design to allow continued roosting by bats cannot be constructed in a bridge replacement, consider alternate roosts specific to the species in question (BCI and SBDN 2013).
  – Don't schedule maintenance on the underside of bridges housing summer

bat colonies when and flightless young and pregnant or lactating females are present. To avoid the maternity period in South Carolina, bats should not be evicted from May through July.

- Exercise caution when conducting maintenance under bridges housing winter bat colonies, as some species such as Rafinesque's big-eared bats, southeastern bats, and eastern small-footed bats are known to use bridges during winter (BCI and SBDN 2013).
- If bats must be excluded from bridges, follow proper exclusion methods and exclusion timing (BCI and SBDN 2013).
- Avoid the creation of bat roosts above exposed metal components as droppings may cause oxidation of unprotected metal bridge parts (BCI and SBDN 2013).
- Discourage maintenance workers from handling bats. When dust from bat droppings cannot be avoided, provide workers with respirators capable of filtering 2 to 3 micron-sized particles (a protection factor of at least 10) (BCI and SBDN 2013).

4.1.4. Talus, cliff faces and other rock formations

- Avoid disturbance of talus and cliff roosting species (where known) from road construction, mining, or reservoir flooding.

4.2. Provide Specific Roost Sites

- Construct suitable artificial roosts specific to each bat species, especially in areas of depleted roosting resources. These structures should provide similar microclimate conditions to natural or anthropogenic roosts used by bats (BCI and SBDN 2013). Typical bat box structures will not suffice for species that prefer large open cavities. Structures that mimic large hollow trees, similar to artificial chimney structures now used for chimney swifts, may be suitable alternative roosts for Rafinesque's big-eared bats and Southeastern bats. Multi-chamber nursery boxes should be erected for significant little brown bat, northern long-eared, and small-footed bat colonies, and large bat towers for Rafinesque's big-eared bats can also be modified to accommodate these species (SCDNR 2015).

5. Monitor and Mitigate Emerging Threats

White-nose Syndrome is currently the most devastating threat facing bats in North American bat populations, and the South Carolina White-nose Response Plan was updated in October of 2017 (SCDNR 2018) to address WNS concerns in the state. Wind energy development, pesticides and environmental contaminants, controlled burning, towers, global climate change, and feral hogs all also pose a threat to South Carolina's bat species.

5.1. WNS

- Coordinate with cooperators and partners of the conservation community in adhering to state and federal WNS Response Plan guidelines and the South Carolina WNS Response Plan.

- Annually contact the Southeastern Cooperative Wildlife Disease Study (SCWDS) to determine if submission of swabs from certain bat species captured in the spring or fall to test for *Pseudogymnoascus destructans (Pd)* are being accepted (SCDNR 2015).
- Collect more temperature data for suitability to *Pd* in the two best known caves by SCDNR on SCPRT land (SCDNR 2018).
- Minimize nonessential research or educational programs without research value that involves handling or disturbance of bats, but continue acoustic surveys of same route(s) for rough population trends (SCDNR 2018).
- Monitor cave/mine roosts to evaluate survivorship, using methods that minimize stress on roosting bats (SCDNR 2018).
- Continue to take WNS disinfection precautions (SCDNR 2018).

5.2. Wind Energy Development

- Work with wind energy development companies to mitigate impacts of wind turbines by making recommendations such as increasing the cut-in speed of turbines (between 1.5 and 3.0 m/s, for example) or turning off selected turbines during peak migration to help reduce mortalities (Arnett et al. 2013, SCDNR 2015).

5.3. Pesticide Poisoning and Environmental Contaminants

- Minimize large-scale pesticide use whenever possible.
- Protect habitat above or around maternity roosts and known foraging areas from pesticides.

5.4. Controlled Burning

- Advise forestry professionals to conduct controlled burns when minimum night temperatures are > 39°F (4°C), temperatures at the time of ignition are > 50°F (10°C) in order to minimize negative impacts to tree bats (Perry and McDaniel 2015, SCDNR 2015). Additionally, smoke propelled by increased wind speeds may increase awareness and more quickly wake bats in leaf litter from torpor (Layne 2009).

5.5. Towers

- Only use flashing lights on towers, rather than lights that are constantly on; this is now regarded as acceptable by the FAA and can reduce bat mortality (SCDNR 2015).

5.6. Global Climate Change

- Employ correlative models using historical and current distributions to evaluate habitat change based on various climate change scenarios, particularly distributions of important roost tree species (BCI and SBDN 2013).

5.7. Feral Hogs

- Control feral hogs through increased hunting and trapping on public land, and encourage the same on private land. Currently, there is no closed hunting season for wild hogs on private lands with a valid hunting license, and it is possible to hunt hogs at night with artificial lights and night vision devices using any legal firearm, bow, or crossbow if SCDNR is given 48 hours' notice. See SCDNR Rules and Regulations at http://www.dnr.sc.gov/regs/pdf/hog.pdf for more information.

6. Identify, Protect, and Enhance Bat Habitat and Drinking Resources

One of the largest and most well known threats to bats is the loss or degradation of important habitat that provides roosting, foraging, and drinking resources to many species in the state. Therefore, efforts that seek to protect and manage these habitats for bats should be a primary concern.

6.1. Identify Occupied Roosting and Foraging Habitat

- Identify known high priority roosting and foraging bat habitats.
- Encourage landowners and land managers to determine the presence or absence of bats, maternity roosts and hibernacula by searching previously unsurveyed public and private lands (BCI and SBDN 2013).

6.2. Protect Roosting and Foraging Habitat and Drinking Resources

- Protect mature bottomland hardwood forests and connecting corridors in the Inner and Outer Coastal Plain, especially for the Rafinesque's big-eared bat. Recruitment of younger stages of high quality bottomland habitat for growth into future roost trees is needed (SCDNR 2015).
- Retain upland forest corridors to prevent isolation of Seminole bats (SCDNR 2015).
- Enforce existing legislation such as the Cave Protection Act of 1988 and the Clean Water Act, Section 404 that protect sites surrounding caves and along riparian corridors in locations near or adjacent to bat roosts, when applicable (BCI and SBDN 2013).
- Manage stream-side management zones (SMZs) to encourage retention of roost-tree species on lands actively managed for timber production (Wigley et al. 2007, BCI and SBDN 2013).

6.3. Manage and Enhance Roosting and Foraging Habitat and Drinking Resources

- Provide forested corridors between harvested units (SCDNR 2015).
- Retain and recruit cypress-gum swamp forests containing large cavity trees (SCDNR 2015).
- Encourage timber management at selected sites in the Piedmont region that creates uncluttered forest such as pine thinning or controlled burns (SCDNR 2015).
- Advocate for management that creates or maintains patches of structurally diverse forest with high densities of large-diameter cavity trees in order to provide a wide variety of suitable roosting and maternity sites (BCI and SBDN 2013).

- Encourage and adhere to forest management actions that retain late succession forests with a relatively open understory, and high structural complexity and species diversity at selected sites for Rafinesque's big-eared bat and the southeastern bat (BCI and SBDN 2013).
- Encourage landowners managing forests that support bat populations to implement Best Management Practices (BMPs; Stringer and Perkins 2001) and create wider SMZ buffers (BCI and SBDN 2013). The functional width of riparian buffer zones near small streams, according to a study by O'Keefe et al. (2013), is greater than or equal to 32 feet (10 m) (though research on larger buffer sizes needs to be conducted).
- Encourage silvicultural prescriptions that produce more open woodland habitat such as partial harvests, mid-story removal, and controlled burning in upland forest habitats. Caution should be used before applying these recommendations to cavity-roosting bats in bottomland hardwood forests, since these prescriptions were studied on mostly upland forest bat species (BCI and SBDN 2013).
- Maintain or increase woody plant diversity. This will provide a diverse and abundant selection of moth prey for species such as Rafinesque's big-eared bat (BCI and SBDN 2013).
- Spatially and temporally provide sufficient older-aged trees in habitat prescriptions accompanying timber harvests (BCI and SBDN 2013).
- Preserve and/or manage for waterways and wetlands that connect lands of different ownership (BCI and SBDN 2013).

7. Conduct Necessary Research

For this conservation plan to be successful, complete and reliable information on abundance, distribution, demography, life history, and habitat needs for many of South Carolina's bat species is needed. Habitat protection plans and land management strategies cannot be fully informed without this essential ecological data.

7.1. For Current Status Assessments

7.1.1. Short-term surveys

- Survey and map mines, tunnels, wells and cave-like structures not surveyed in previous efforts in order to locate hibernacula (SCDNR 2015).
- Determine alternate roost sites for bridge roosting Rafinesque's big-eared bats (SCDNR 2015).
- Locate and map roost trees by physical searches where possible for Rafinesque's big-eared bats (SCDNR 2015).
- Obtain basic information on colony size, composition, dynamics, and determine how these vary with roost site characteristics, especially for the southeastern bat (SCDNR 2015).
- Identify colonies of eastern small-footed bats, little brown bats, northern long-eared bats, southeastern bats, and tricolored bats (SCDNR 2015).

- Identify priority areas for field surveys for northern yellow bats (SCDNR 2015).
- Determine northern yellow bat distribution in the Carolinas through surveys (SCDNR 2015).
- Locate significant northern yellow bat roost sites through survey efforts (SCDNR 2015).
- Establish dependable estimates of range-wide population sizes, especially for Rafinesque's big-eared bat (BCI and SBDN 2013).

7.2. For Life History and Habitat Needs

7.2.1. Short-term research projects

Roosting Habitat

- Evaluate roost availability along with roost temperature and the availability of appropriate food (insects high in polyunsaturated fats) compared to winter survival (SCDNR 2015).
- Determine summer and winter roost site requirements, including temperature and humidity measurements, for eastern small-footed bat, Rafinesque's big-eared bat, southeastern bat, silver-haired bat, and all lasiurine bat species (BCI and SBDN 2013, SCDNR 2015).
- Use existing data on habitat preferences to identify the availability of natural roost habitat and to determine the amount of protected versus unprotected habitat, especially for Rafinesque's big-eared bat and southeastern bat (SCDNR 2015).
- Using landscape factors that influence roost habitat quality, determine roosting habitat requirements for southeastern bats (SCDNR 2015).
- Establish methods that promote roost switching of southeastern bats to alternate sites when exclusion from a structure cannot be avoided (BCI and SBDN 2013).
- Determine preferred roosting microclimates inside artificial structures for southeastern bats (BCI and SBDN 2013).
- Assess placement, habitat conditions, and structural configuration for artificial structures used by Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).
- Determine buffer sizes required to protect roosts of South Carolina's highest priority bat species.
- Determine the efficacy of roost buffers by assessing how roost tree longevity, use, and internal microclimate are affected by the configuration and extent of surrounding habitat influences, especially for Rafinesque's big-eared bat and the southeastern bat (BCI and SBDN 2013).

- Obtain spatial and temporal data on roost tree densities in South Carolina, especially for Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).
- Establish the minimum number of roost trees required to support Rafinesque's big-eared bat and southeastern bat populations in bottomland hardwood forests, as well as the other highest priority bat species in South Carolina (BCI and SBDN 2013).
- Calculate the approximate annual survival of hollow tree roosts in bottomland hardwood forests (BCI and SBDN 2013).

Foraging Habitat

- Determine foraging habitat requirements such as habitat types, size, and distance from roosts for highest priority bat species, especially northern long-eared bats and Rafinesque's big-eared bats (SCDNR 2015).
- Determine connections between forest structure and foraging success, especially for Rafinesque's big-eared bats (BCI and SBDN 2013).
- Calculate approximate home range sizes and geographical use of available foraging habitats, especially for southeastern bats (BCI and SBDN 2013).

Diet

- Study the feeding ecology requirements for all South Carolina bats, especially for southeastern bats and Rafinesque's big-eared bats in the mountains and Coastal Plain (BCI and SBDN 2013, SCDNR 2015).

Migration Patterns

- Research migration routes, timing, patterns and seasonal movements of the hoary bat, red bat, silver-haired bat, southeastern bat, and tricolored bat (BCI and SBDN 2013, SCDNR 2015) .
- Determine where South Carolina's over-wintering silver-haired bat population migrates over summer, potentially through stable isotope research from hair or nail samples (SCDNR 2015).

Social Organization and Behavior

- Ascertain more detailed information on colony patterns of social organization and behavior, especially for Rafinesque's big-eared bats (BCI and SBDN 2013).
- Examine the maternity colony roosting behavior of southeastern bats (BCI and SBDN 2013).

Longevity and Survival

- Calculate the estimated longevity and age-related survival for Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).

Land Management

- Determine the effects of habitat fragmentation and roads on foraging behavior of Rafinesque's big-eared bats, southeastern bats, and northern long-eared bats (BCI and SBDN 2013, SCDNR 2015).
- Determine how roost selection and foraging behavior are affected by forest management, especially in bottomland hardwood forests on Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013), but also for northern long-eared bats.
- Examine the effects of selective thinning, cutting, and extended rotation lengths, especially in bottomland hardwood forests on Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013) but also for northern long-eared bats.
- Examine the effect of SMZ width and extent of corridor fragmentation allowable in upland forests (BCI and SBDN 2013).
- Compare foraging and roosting habitat use with stream buffer dimensions (BCI and SBDN 2013).

WNS

- Determine how exposure to the *Pd* fungus affects Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).

Wind Energy

- Identify the best placement of wind turbines, as well as other strategies that would minimize wind energy impacts to South Carolina's bats.
- Determine the extent of coastal and off-shore foraging and commuting and its seasonality to assess vulnerability of lasiurine bats to off-shore and coastal wind energy development, particularly during fall migration (SCDNR 2015).
- Study potential impacts from wind farms and develop strategies to reduce silver-haired bat mortality (SCDNR 2015).
- Calculate estimated mortality rates at wind turbines located near roosting sites of Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).

Fire

- Determine if prescribed fire presents any threats to Rafinesque's big-eared bats, eastern small-footed bats, southeastern bats, or silver-haired bats (SCDNR 2015).
- Determine acceptable distance of fire, smoke and fire lines from roosts (SCDNR 2015), especially for northern long-eared bats.
- Examine the impacts of winter burns during cold weather on silver-haired bats (particularly on south-facing burn units) (SCDNR 2015).
- Evaluate prescribed fire for enhancement of bat habitat (BCI and SBDN 2013).

Pesticides and Heavy Metals

- Determine if northern yellow bats, silver-haired bats, and southeastern bats are threatened by pesticide and/or heavy metal contamination (SCDNR 2015).

Introduced Predators

- Determine if unnatural predation at roosts by feral cats is occurring. Study sites should include the southeastern bat roost at Orangeburg State Park (SCDNR 2015).

Climate Change

- Collect reliable information on how bats respond to potentially higher temperatures and an increased need for water (BCI and SBDN 2013).
- Create correlative models using historical and current distributions to evaluate habitat change based on various climate change scenarios in the state, particularly distributions of important roost tree species in South Carolina (BCI and SBDN 2013).

Acoustic Monitoring

- Continue to improve acoustic monitoring, such as increasing call identification accuracy for all of South Carolina's bat species, particularly those with similar calls from sympatric *Myotis* species (BCI and SBDN 2013).

7.3. For Demography, Distribution and Abundance

7.3.1. Long-term monitoring

- Follow protocols outlined in the 2015 Plan for the North American Bat Monitoring Program (NABat) (http://www.srs.fs.usda.gov/pubs/gtr/gtr_srs208.pdf). This is a continental program to monitor and track bat populations at local and range wide scales to provide reliable data for conservation decision making and long-term bat population viability. Data is collected using winter hibernacula counts, maternity colony counts, mobile acoustic surveys along road transects, and stationary acoustic surveys. For acoustic surveys in South Carolina, a grid of 30 surveyable cells 10 km by 10 km in size was developed by USGS and implementation has been initiated by Ben Neece (http://myweb.clemson.edu/~bneece/about.php).
- Monitor any winter colonies of South Carolina's bats, especially little brown bats (SCDNR 2015).
- Conduct demographic studies on little brown bats to measure the effects of WNS if it occurs (SCDNR 2015).
- Obtain long-term demographic data including reproductive success, sex ratios, survival, immigration and emigration facilitated by dispersal, and determine the effects of biotic and abiotic factors on these parameters for Rafinesque's big-eared bats and southeastern bats (SCDNR 2015).
- Begin long-term monitoring on colony size, persistence, and roost sites for eastern small-footed bats (once colonies are found) and southeastern bats

(SCDNR 2015).

- Monitor significant northern yellow bat roost sites for continued usage (SCDNR 2015).
- Conduct annual maternity season surveys for Rafinesque's big-eared bat and the southeastern bat at cave or mine entrances using IR camera when young are flightless, and again soon after volancy begins, to assess colony size changes and determine reproductive success of the maternity colony. When both surveys can't be completed during the same season due to time and resource constraints, complete only the post-volancy survey (BCI and SBDN 2013).
- Conduct distribution and abundance surveys on southeastern bats in order to compile more complete data (BCI and SBDN 2013).
- Survey all historically occupied roosts, especially for southeastern bats (BCI and SBDN 2013).
- Conduct building and bridges surveys, especially for significant bat hibernacula and maternity colonies in South Carolina.

7.4. For Metapopulation Studies and Population Connectivity

7.4.1. Long-term research studies

- Create a statistically-robust sampling strategy to estimate range-wide population sizes of bats using counts during hibernation and maternity periods (BCI and SBDN 2013).
- Develop inventory and monitoring approaches that can detect biologically meaningful changes in bat population size (BCI and SBDN 2013).
- Determine how habitat connectivity and patch size affect movements, colony size, frequency of dispersal, and gene flow, especially for Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).
- Establish research and survey protocols that allow for comparisons across bat habitat and bat populations (BCI and SBDN 2013).
- Determine the minimum habitat patch size requirement to support specific bat colonies of over time, especially for Rafinesque's big-eared bats and southeastern bats (BCI and SBDN 2013).

7.5. For Genetic Diversity and Effective Population Size

7.5.1. Genetics-based research studies

- Determine the genetic structure of selected colonies of Rafinesque's big-eared bats and southeastern bats, and test whether populations are experiencing adverse genetic consequences from isolation and fragmentation (SCDNR 2015).
- Conduct molecular research to determine the validity of the northern yellow bat subspecies designation and the variation within the species across its known distribution (SCDNR 2015).

8. Provide Education, Extension, and Outreach

A large piece of any effective conservation strategy involves working to create comprehensive public and environmental education programs and increase the visibility of species being threatened. Educational programs should focus on why the existence of South Carolina's bat species across the landscape is essential, and provide details on how to help prevent population declines. Additionally, as suggested by Bat Conservation International and the Southeastern Bat Diversity Network (BCI and SBDN 2013), *"clearly written guidelines for land management need to be developed and distributed to lawmakers, decision makers, enforcement officials, landowners, and the general public to foster pro-active habitat management. These guidelines should include strategies for recruiting roost tree species, options for sustainable timber management practices, information about laws and legal issues affecting bats, and tools for protecting bat roosts from disturbance and alteration, while reducing landowner liability."*

8.1. General Public

8.1.1. Conduct outreach for prevention of WNS

- SCDNR staff and SCDNR spokesperson will continue to coordinate press releases with the USFWS WNS information/outreach specialist to educate the public and update elected officials (SCDNR 2018).
- Inform the public to report unusual die-offs to their regional wildlife biologists for submission for testing (SCDNR 2018).
- Work with caving clubs such as the South Carolina Interstate Grotto to assist with WNS education and outreach (SCDNR 2018).

8.1.2. Educate home owners, landowners and land managers

- Inform landowners and land managers about the importance of bats on their land, along with the current conservation status of each of South Carolina's bats (BCI and SBDN 2013).
- Encourage landowners and land managers to search previously un-surveyed public and private lands by providing effective survey methodologies that will help determine presence or absence of bats and assist in locating potential maternity roosts and hibernacula (BCI and SBDN 2013).
- Discourage the practice of removing roosting habitat such as old palm fronds and large amounts of Spanish moss from trees (SCDNR 2015).
- Create demonstration areas on publicly owned site(s), leaving old fronds uncut on palms in a highly visible area with prominent signage explaining that old fronds provide important roosting habitat for northern yellow bats (SCDNR 2015).
- Emphasize conservation of Rafinesque's big-eared bat throughout its entire range (BCI and SBDN 2013).
- Develop clearly written guidelines to help promote pro-active bat habitat management (BCI and SBDN 2013).

8.1.3. Develop and distribute informational materials

- Develop and distribute brochures and study plans.
- Develop more interactive websites. For example, a successful occupied bat box can now be reported online at http://www.dnr.sc.gov/wildlife/bats/batbox.html.
- Make human-made alternate roost design plans and placement guides for bat houses, as well as clearly written guidelines for bat habitat management, available as pdf documents to be shared with both the public and organizations such as the South Carolina Wildlife Federation (SCWF) (BCI and SBDN 2013, SCDNR 2015).

8.1.4. Increase the visibility of bats

- Provide bat species information for, and generate interest through, social media.
- Create a bat watch program where the public counts bats exiting known roosts to measure population declines, similar to the program in Pennsylvania. This would require a set up of a data file and an online reporting page for the public (SCDNR 2018).

8.2. Specialized Audiences

8.2.1. Private Landowner Caves

- Conduct outreach to prevent disturbance to bat colonies in private caves.

8.2.2. Federal Highway Administration and SCDOT

- Develop a strategy for outreach and education in order to protect bat roosts and habitats during and after road construction, bridge replacement, and bridge maintenance (BCI and SBDN 2013, SCDNR 2015).

8.2.3. Wildlife Control Operators (WCOs)

- Require certification of WCOs that includes exclusion training, restrictions or recommendations on appropriate timing of exclusion, and mandatory notification of SCDNR if any colonial roosting bat species (big brown bat, eastern small-footed bat, little brown bat, northern long-eared bat, Rafinesque's big-eared bat, southeastern bat, or tricolored bat) are involved. Clemson University's Pesticide Regulation and Control, Clemson Extension, and SCDNR could partner in training and administering this program (SCDNR 2015).

9. Partner with Agencies, Landowners, and Other Groups

Partnerships and cooperation between government agencies, private landowners, non-governmental organizations, and the public are essential if South Carolina is to accomplish the conservation objectives set out in this plan.

9.1. Develop State and Federal Agency Partnerships with Land Owners

- Utilize the Cooperative Extension Programs at land grant universities (BCI and SBDN 2013).

9.2. Provide Conservation Incentives

- Bat habitat protections may be accomplished through landowner incentive programs, conservation easements, lease agreements, purchases, stewardship and management agreements, and means of financial assistance (BCI and SBDN 2013, SCDNR 2015).
- Encourage conservation-friendly tax structures that reward habitat protection, water conservation, and sustainable forestry practices (BCI and SBDN 2013).
- Promote already existing state and federal programs that manage forests, wetlands, and roosting resources of bats (BCI and SBDN 2013).

9.3. Reconvene a Mammal Taxa Team to Evaluate State Rankings

- Invite bat experts from all sources, including state, federal, universities, and nonprofit organizations to re-evaluate current state rankings and recommend new rankings if necessary. SCDNR Chief of Wildlife Statewide Projects, Derrell Shipes, has initiated the review of all species' rankings.

10. Integrate and Maintain the South Carolina Bat Conservation Plan

To ensure conservation strategies are applied on the landscape, including them in other management plans is necessary. Also, conservation priorities and strategies are dynamic, so updates that reflect recent changes and include new scientific information are vital to an accurate and relevant bat conservation strategy.

10.1. Integrate bat conservation into other management plans

- Incorporate bats, particularly those of conservation concern, into forest and other land management plans (SCDNR 2015). For example:
    - Maintain large, cavity-producing trees and provide future roost trees in forest management planning on federal and private lands (BCI and SBDN 2013).

10.2. Keep the South Carolina Bat Conservation Plan Up to Date

- Update and revise this conservation plan every 2-5 years with current scientific information and additional land management strategies.
- Reevaluate species designations if new evidence suggests the status of bat species should be changed at the state level.

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Appendix A

SOUTH CAROLINA CODE OF REGULATIONS

CHAPTER 123
Department of Natural Resources

ARTICLE 5
Non-game and Endangered Species

123-150 Non-Game and Endangered Species.

1. The following list of species or subspecies of non-game wildlife are faced with extinction in the foreseeable future and are added to the official State List of Endangered Wildlife Species of South Carolina.

I. Birds
1. Bachman's Warbler (Vermivora bachmanii)
2. Bewick's Wren (Thryomanes bewickii)
3. Eskimo Curlew (Numenius borealis)
4. Kirtland's Warbler (Dendroica kirtlandii)
5. Piping Plover (Charadrius melodus)
6. Red-cockaded Woodpecker (Picoides borealis)
7. Swallow-tailed Kite (Elanoides forficatus)
8. Wood Stork (Mycteria americana)

II. Fish
1. Shortnose Sturgeon (Acipenser brevirostrum)
2. Pinewoods Darter (Etheostoma mariae)

III. Mammals
1. Atlantic Right Whale (Eubalaena glacialis)
2. Blue Whale (Balaenoptera musculus)
3. Bowhead Whale (Balaena mysticetus)
4. Eastern Cougar (Felis concolor cougar)
5. Finback Whale (Balaenoptera physalus)
6. Florida Manatee (Trichechus manatus)
7. Humpback Whale (Megaptera novaengliae)
8. Indiana Bat (Myotis sodalis)
9. Sei Whale (Balaenoptera borealis)
10. Sperm Whale (Physeter catodon)
11. Rafinesque's Big-eared Bat (Plecotus rafinesquii)

IV. Reptiles
1. Atlantic Leatherback Turtle (Dermochelys c. coriacea)
2. Atlantic Ridley Turtle (Lepidochelys kempii)
3. Gopher Tortoise (Gopherus polyphemus)
4. Atlantic Hawksbill Sea Turtle (Eretmochelys imbricata)

V. Amphibians

1. Flatwoods Salamander (Ambystoma cingulatum)
2. Webster's Salamander (Plethodon websteri)
3. Carolina Gopher Frog (Rana c. capito)

VI. Molluscs

1. Atlantic Pigtoe Mussel (Fusconaia masoni)
2. Brother Spike Mussel (Elliptio fraterna)

2. It shall be unlawful for any person to take, possess, transport, export, process, sell, or offer for sale or ship, and for any common carrier knowingly to transport or receive for shipment any species or subspecies of wildlife appearing on the list of "Endangered Wildlife Species of South Carolina", except by permit for scientific and conservation purposes issued by the South Carolina Department of Natural Resources.

Permits for conservation purposes shall be issued only for relocation, if warranted, and the incidental take of Red-cockaded Woodpeckers as part of the statewide Habitat Conservation Plan for Safe Harbor and for other mitigation purposes approved by the U.S. Fish and Wildlife Service.

3. The penalty for the violation of this Rule and Regulation shall be that prescribed by 50-15-80, 1976 S.C. Code of laws.

HISTORY: Amended by State Register Volume 18, Issue No. 5, eff May 27, 1994; State Register Volume 22, Issue No. 4, eff April 24, 1998; State Register Volume 26, Issue No. 6, Part 2, eff June 28, 2002; State Register Volume 31, Issue No. 6, eff June 22, 2007; State Register Volume 33, Issue No. 8, eff August 28, 2009.

123-150.1 Cheloniidae and Dermochelyidae (Sea Turtles).

1. The remaining species of the families Cheloniidae and Dermochelyidae (sea turtles) not listed in South Carolina Wildlife and Marine Resources Department Regulation 123-150 are considered threatened and in need of management.

2. That is shall be unlawful for any person to take, possess, barter, trade, transport, export, process, sell or offer for sale or ship, and for any contract carrier knowingly to transport or receive for shipment any such species or products or parts or eggs thereof except by permit for scientific or educational purposes issued by the South Carolina Wildlife and Marine Resources Department, except that incidental catch of sea turtles while engaged in otherwise legal fishing, trawling or research activities at sea would be exempt under the taking clause of this regulation.

3. Sea turtles captured incidentally to legal fishing and/or research activities which appear vigorous when removed from the net, will be immediately returned to the water, exercising due care to prevent injury. Release should be from a location on the vessel which will minimize the possibility of the turtle being damaged by the vessel's propeller. The release will be made only when all sets of trawl doors or otter boards are hanging from the boom or outriggers.

4. Sea turtles which show no sign of life or those that are obviously weak, will be turned on their back and held on deck until they regain their strength or it appears that the turtle is definitely dead. In no cases, will weakened or apparently dead turtles be released until they have been held on deck for 30 minutes and attempts at revival have been made, i.e., pressing or pumping plastron (belly shell) to expel water and stimulate breathing.

5. That the penalty for the violation of this Rule and Regulation shall be prescribed by Section 50-15-80, 1976 South Carolina Code of Laws, as amended.

6. That except as modified or changed hereby, all prevailing laws, rules and regulations concerning wildlife in South Carolina shall remain in full force and effect.

123-150.2 Birds, Fish, Reptiles, Amphibians and Mammals.

The following list of species or subspecies of non-game wildlife are considered to be threatened and are added to the official state list of Non-game Species in Need of Management.

I. Birds
1. American Peregrine Falcon (Falco peregrines anatum)
2. Bald Eagle (Haliaeetus leucocephalus)
3. Bewick's Wren (Thryomanes bewickii)
4. Common Ground Dove (Columbina passerina)
5. Least Tern (Sterna albifrons)
6. Wilson's Plover (Charadrius wilsonia)

II. Fish
1. Carolina Pygmy Sunfish (Elassoma boehlkei)
2. Broadtail Madtom (Noturus sp.)

III. Reptiles
1. American Alligator (Alligator mississippiensis)
2. Atlantic Loggerhead Sea Turtle (Caretta caretta)
3. Atlantic Green Sea Turtle (Chelonia mydas)
4. Coal Skink (Eumeces anthracinus)
5. Bog Turtle (Clemmys muhlenbergii)
6. Spotted Turtle (Clemmys guttata)
7. Southern Hognose Snake (Heterodon simus)

IV. Amphibians
1. Dwarf Siren (Pseudobranchus striatus)
2. Pine Barrens Treefrog (Hyla andersonii)

V. Mammals
1. Small-footed Bat (Myotis leibii)

HISTORY: Amended by State Register Volume 18, Issue No. 5, eff May 27, 1994; State Register Volume 26, Issue No. 6, Part 2, eff June 28, 2002; State Register Volume 31, Issue No. 6, eff June 22, 2007; State Register Volume 33, Issue No. 8, eff August 28, 2009.

123-150.3 Scientific Collecting Permit Required.

That a scientific collecting permit under the terms of Section 50-11-2190, 1976 Code of Laws, shall be required for the collecting of all nongame species or subspecies of the Classes Pices (Fish), Amphibia (Amphibians), Reptilia (Reptiles), Aves (Birds) and Mammalia (Mammals).

SOUTH CAROLINA CODE OF LAWS

CHAPTER 11
Protection of Game

ARTICLE 6
Special Depredation Permits, Collection Permits, Closing Seasons, Special Seasons

SECTION 50-11-1180. Authority of department to issue permits to collect protected wildlife for scientific or propagating purposes; penalties.

For purposes of this section:

(a) "Take" means to harass, hunt, capture, or kill.

(b) "Protected wildlife" means any wildlife, part, product, egg, offspring nest, dead body, or part thereof which is managed or protected or the taking of which is specifically regulated by the department.

Permits may be granted by the department to any properly accredited competent person permitting him to collect protected wildlife for strictly scientific or propagating purposes only. No permit is required for the collecting or taking of nonprotected wildlife. Applications for a permit must be made to the department which shall investigate the applicant and the project or program for which the collection is to be made. The application must be accompanied by a payment of a ten-dollar fee to cover the cost of the examination and the issuing of the permit. If the department considers the applicant to be qualified and the program or project to be necessary or desirable, it shall issue a permit which expires on December thirty-first of the year in which it is issued. Permits may be renewed for one year upon application and the payment of a ten-dollar renewal fee if the department determines the applicant and the program or project is still qualified. Permits are not transferable but any student assistant working under the direct supervision of the permittee in collecting activities may participate under the permit. All collecting or taking must be conducted so as to adhere to recognized scientific methods. Wherever practicable, data, results, and specimens must be made available to the public upon request. The permittee shall submit a report at the end of the permit period of the specimens collection and of other information as may be included on the report form, which must be furnished by the department. Collecting permits for endangered species must be issued only in accordance with Section 50-15-40. The provisions of Section 50-17-70;;;MI;;0000000; are not superseded by the provisions of this section.

Any person violating the provisions of this section is guilty of a misdemeanor and, upon conviction, must be fined in an amount of not less than twenty-five dollars nor more than one hundred dollars or imprisoned for a term not to exceed thirty days and any permit issued to that person is revoked.

HISTORY: [Derived from former Sections 50-1130 (1962 Code Section 28-303; 1952 Code Section 28-303; 1942 Code Section 1787; 1932 Code Section 1787; Cr. C. '22 Section 740; 1919 (31) 269; 1952 (47) 2179); 50-11-2190 (1962 Code Section 28-469; 1968 (55) 2430; 1979 Act No. 148, Section 1)]; 1988 Act No. 561, Section 1; 1993 Act No. 181, Section 1262.

ARTICLE 10
Wildlife Management Areas

SECTION 50-11-2200. Establishment, operation, and maintenance of wildlife management areas; prohibited conduct; penalties.

(A) Subject to available funding, the department shall acquire sufficient wildlife habitat through lease or purchase or otherwise to establish wildlife management areas for the protection, propagation, and promotion of fish and wildlife and for public hunting, fishing, and other natural resource dependent recreational use. The department may not have under lease at any one time more than one million six hundred thousand acres in the wildlife management area program. The department may not pay more than fair market value for the lease of lands in the area. The department may not lease land for the program which, during the preceding twenty-four months, was held under a private hunting lease. However, this restriction does not apply:

(1) if the former lessee executes a voluntary consent to the proposed wildlife management area lease;

(2) if the lessor cancels the lease; or

(3) to any lands which, during the twenty-four months before June 5, 1986, were in the game management area program.

(B) The department may promulgate regulations for the protection, preservation, operation, maintenance, and use of wildlife management areas and Heritage Trust areas and those other lands owned by the department.

(C) The following acts or conduct are prohibited and shall be unlawful on all wildlife management areas, state lakes and ponds owned or leased by the department, heritage preserves owned by the department, and all other lands owned by the department; provided, however, the department may promulgate regulations allowing any of the acts or conduct by prescribing acceptable times, locations, means, and other appropriate restrictions not inconsistent with the protection, preservation, operation, maintenance, and use of such lands and areas:

(1) hunting or taking wildlife or fish;
(2) exceeding bag or creel limits;
(3) hunting or taking wildlife or fish by unauthorized methods, weapons, or ammunition;
(4) hunting or taking wildlife or fish during closed seasons, days, or times;
(5) hunting or taking wildlife by aid of bait or feeding or baiting wildlife;
(6) hiking;
(7) rock climbing or rappelling;
(8) operation of motorized and nonmotorized vehicles;
(9) swimming;
(10) camping;
(11) horse riding;
(12) staging or participating in “paintball”, “airsoft”, or similar games;
(13) possession of pets and specialty animals;
(14) use of fire, fireworks, or explosives;
(15) polluting or contaminating any land or water;
(16) acting in a disorderly manner or creating any noise which would result in annoyance to others and no person shall operate or use electronic sound devices except as permitted by the department;

(17) consumption of alcoholic beverages or possession of open containers of alcoholic beverages on lands and areas designated for hunting or fishing;
(18) conducting commercial activity or using the area for commercial gain, except by permit;
(19) gathering, damaging, or destroying rocks, minerals, fossils, artifacts, geological formations, or ecofacts, except by permit;
(20) gathering, damaging, or destroying plants, fallen vegetation, animals, and fungi except to the extent these activities are authorized by permit, or are incidental to other activities authorized in wildlife management areas by this title;
(21) entering a closed area or unauthorized entry;
(22) launching or landing parachutes or parasails or aircraft including models or remotely piloted aircraft and similar devices, except for law enforcement or emergencies;
(23) placing temporary or permanent structures on these lands and areas, except permitted stands and blinds;
(24) obstructing or creating a hazard to land or water traffic or obstructing a watercourse;
(25) operating a motor vehicle in or across watercourses other than at designated fording sites;
(26) posting bills, signs, or other notices;
(27) indecently exposing one's person or performing an indecent act in public;
(28) abandoning vehicles, equipment, or other material;
(29) defacing, altering, destroying, or removing any sign, marker, guidepost, fence, gate, lock, barrier, improvement, building, bridge, culvert, structure, natural landmark, or feature;
(30) geocaching;
(31) use or possession of metal detectors, except by permit;
(32) digging or excavating, except by permit;
(33) use of herbicides or pesticides, excluding insect repellent;
(34) introducing nonnative or cultivated plants or other organisms, or releasing an animal;
(35) cutting or collecting of firewood, except by permit;
(36) discharging weapons or target shooting, except in areas designated by the department;
(37) trapping;
(38) shooting onto or across WMA areas closed to hunting or attempting to take wildlife on WMA areas closed to hunting;
(39) use or operation of watercraft; and
(40) depositing refuse, garbage, or other waste materials.

(D) The department or emergency service personnel may undertake these activities for enforcement, emergencies, or management purposes.

(E) A person violating this section is guilty of a misdemeanor and, upon conviction, must be fined not less than twenty-five dollars nor more than two hundred dollars or be imprisoned for not more than thirty days, or both.

(F) As used in this section "bait", "baiting", or "feeding" means placing, depositing, exposing, distributing, or scattering of shelled, shucked, or unshucked corn, wheat, or other grain or food stuffs to constitute an attraction, lure, or enticement for wildlife to, on, or over an area. "Baited area" means an area where bait or feed is directly or indirectly placed, deposited, exposed, distributed, or scattered, and the area remains a baited area for ten days following the complete removal of all bait or feed. Nothing in this section prohibits the hunting and taking of wildlife on or over lands or areas that are not otherwise baited and where:

(1) there are standing crops on the field where grown, including crops grown for wildlife management purposes; or

(2) shelled, shucked, or unshucked corn, wheat, or other grain, or seeds that have been distributed or scattered solely as the result of a normal agricultural practice as prescribed by the Clemson University Extension Service or its successor.

(G) An activity permitted by regulation may be temporarily suspended for up to one hundred eighty days if the activity is adversely affecting natural resources or human health or safety.

(H) Nothing contained in this section shall interfere with the use and management of lands by a state agency in charge of these lands in the functions of the agency as authorized by law.

HISTORY: 1988 Act No. 561, Section 1; 1993 Act No. 181, Section 1262; 1996 Act No. 372, Section 3; 2001 Act No. 70, Section 1; 2007 Act No. 84, Section 1, eff June 14, 2007; 2009 Act No. 63, Section 1, eff June 2, 2009; 2014 Act No. 234 (S.1177), Section 1, eff June 2, 2014.

SECTION 50-11-2210. Abuse of wildlife management area land, Heritage Trust land, or department owned land or improvements; penalties.

The abuse, misuse, damage, or destruction of wildlife management area land, Heritage Trust land, or department owned land or improvements on these lands is unlawful. A person who abuses, misuses, damages, or destroys these lands or improvements on them including, but not limited to, roads, vegetation, buildings, structures, or fences or leaves refuse, trash, or other debris on the property, or who otherwise abuses, damages, destroys, or misuses these lands is guilty of a misdemeanor and, upon conviction, must be fined two hundred dollars and be required to make restitution to the landowner in an amount determined by the court to be necessary to repair, rebuild, clean up, or restore the property to its condition before the abuse occurred. A person failing to make restitution within the time limit set by the court must serve a mandatory ten-day sentence in the county jail which may not be suspended in whole or in part. The provisions of this section are in addition to other criminal penalties.

HISTORY: [Derived from former Section 50-11-1610 (1986 Act No. 502, Part II, Section 2)]; 1988 Act No. 561, Section 1; 1993 Act No. 181, Section 1262; 2002 Act No. 257, Section 1; 2009 Act No. 63, Section 2, eff June 2, 2009.

SECTION 50-11-2220. Abuse of wildlife area land, Heritage Trust land, or department owned land or improvements; additional penalties.

A person convicted of abusing, damaging, or destroying wildlife management area land, Heritage Trust land, or department owned land or improvements loses the privilege of entering onto these lands for one year. A person who enters onto wildlife management land, Heritage Trust land, or department owned land after losing the privilege to enter is guilty of a misdemeanor and, upon conviction, must be fined not less than two hundred dollars nor more than five hundred dollars or imprisoned for not more than thirty days, or both and, in addition, shall lose the privilege to enter these lands for an additional two years and the privilege to hunt and fish for one year. The provisions of this section are in addition to other criminal penalties.

HISTORY: [Derived from former Section 50-11-1620 (1986 Act No. 502, Part II, Section 2)]; 1988 Act No. 561, Section 1; 1993 Act No. 181, Section 1262; 2002 Act No. 257, Section 2; 2007 Act No. 84, Section 2, eff June 14, 2007; 2009 Act No. 63, Section 3, eff June 2, 2009.

SOUTH CAROLINA CODE OF LAWS

CHAPTER 15
Nongame and Endangered Species

ARTICLE 1
Nongame and Endangered Wildlife Species

SECTION 50-15-10. Definitions.

As used in this article:

(1) "Ecosystem" means a system of living organisms and their environment, each influencing the existence of the other and both necessary for the maintenance of life.

(2) "Endangered species" means any species or subspecies of wildlife whose prospects of survival or recruitment within the State are in jeopardy or are likely within the foreseeable future to become so due to any of the following factors:

(a) the destruction, drastic modification, or severe curtailment of its habitat, or

(b) its over-utilization for scientific, commercial, or sporting purposes, or

(c) the effect on it of disease, pollution, or predation, or

(d) other natural or manmade factors affecting its prospects of survival or recruitment within the State, or

(e) any combination of the foregoing factors. The term shall also be deemed to include any species or subspecies of fish or wildlife appearing on the United States' List of Endangered Native Fish and Wildlife as it appears on July 2, 1974, (Part 17 of Title 50, Code of Federal Regulations, Appendix D) as well as any species or subspecies of fish and wildlife appearing on the United States' List of Endangered Foreign Fish and Wildlife (Part 17 of Title 50 of the Code of Federal Regulations, Appendix A), as such list may be modified hereafter.

(3) "Management" means the collection and application of biological information for the purposes of increasing the number of individuals within species and populations of wildlife up to the optimum carrying capacity of their habitat and maintaining such levels. The term includes the entire range of activities that constitute a modern scientific resource program including, but not limited to, research, census, law enforcement, habitat acquisition and improvement, and education. Also included within the term, when and where appropriate, is the periodic or total protection of species or populations as well as regulated taking.

(4) "Nongame species" means any wild mammal, bird, amphibian, reptile, fish, mollusk, crustacean, or other wild animal not otherwise legally classified by statute or regulation of this State as a game species.

(5) "Optimum carrying capacity" means that point at which a given habitat can support healthy populations of wildlife species, having regard to the total ecosystem, without diminishing the ability of the habitat to continue that function.

(6) "Person" means any individual, firm, corporation, association, or partnership.

(7) "Take" means to harass, hunt, capture, or kill or attempt to harass, hunt, capture, or kill wildlife.

(8) "Wildlife" means any wild mammal, bird, reptile, amphibian, fish, mollusk, crustacean, or other wild animal or any part, product, egg or offspring, or the dead body or parts thereof.

HISTORY: 1962 Code Section 28-726; 1974 (58) 2384; 1993 Act No. 181, Section 1264; former 1976 Code Section 50-15-20; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-20. Investigations on nongame wildlife by department; regulations; management programs; public hearings; prohibited acts.

(A) The department shall conduct investigations on nongame wildlife in order to develop information relating to population, distribution, habitat, needs, limiting factors, and other biological and ecological data to determine management measures necessary for their continued ability to sustain themselves successfully. On the basis of such determinations the department shall issue proposed regulations and develop management programs designed to ensure the continued ability of nongame wildlife to perpetuate themselves successfully. Such proposed regulations shall set forth species or subspecies of nongame wildlife which the department deems in need of management pursuant to this section, giving their common and scientific names by species or subspecies. The department shall conduct ongoing investigations of nongame wildlife and may from time to time amend such regulations by adding or deleting therefrom species or subspecies of nongame wildlife.

(B) The department shall by such regulations establish proposed limitations relating to taking, possession, transportation, exportation, processing, sale or offer for sale, or shipment as may be deemed necessary to manage such nongame wildlife.

Such regulation shall become effective sixty days after being proposed during which period public comment shall be solicited and received. The board may hold a public hearing if deemed appropriate. On the basis of public comments received or the testimony at any such hearing the department may make such changes in the proposed regulation as are consistent with effective management of nongame wildlife.

(C) Except as provided in regulations issued by the department, it shall be unlawful for any person to take, possess, transport, export, process, sell, or offer for sale or ship nongame wildlife deemed by the department to be in need of management pursuant to this section. Subject to the same exception, it shall further be unlawful for any common or contract carrier knowingly to transport or receive for shipment nongame wildlife deemed by the department to be in need of management pursuant to this section.

HISTORY: 1962 Code Section 28-728; 1974 (58) 2384; 1993 Act No. 181, Section 1264; former 1976 Code Section 50-15-30; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-30. Endangered species listed; review and amendment of list; unlawful to take, deal in, or transport species on lists.

(A) On the basis of investigations on nongame wildlife provided for in Section 50-15-20 and other available scientific and commercial data, and after consultation with other state agencies, appropriate federal agencies, and other interested persons and organizations, but not later than one year after July 2, 1974, the department shall by regulation propose a list of those species or subspecies of wildlife indigenous to the State which are determined to be endangered within this State, giving their common and scientific names by species and subspecies. Such regulation shall become effective sixty days after being proposed during which period public comment shall be solicited and received. The board may hold a public hearing if deemed appropriate. On the basis of public comments received or the testimony at any such hearing, the department may add to such proposed list additional species or subspecies which are determined to be endangered within the State or delete therefrom such species or subspecies which are determined not to be endangered within the State.

(B) The board shall conduct a review of the state list of endangered species within not more than two years from its effective date and every two years thereafter and may amend the list by such additions or deletions as are deemed appropriate. The board shall submit to the Governor a summary report of the data used in support of all amendments to the state list during the preceding biennium.

(C) Except as otherwise provided in this article, it shall be unlawful for any person to take, possess, transport, export, process, sell or offer for sale, or ship, and for any common or contract carrier knowingly to transport or receive for shipment any species or subspecies of wildlife appearing on any of the following lists:

(1) the list of wildlife indigenous to the State determined to be endangered within the State pursuant to subsection (A);

(2) the United States' List of Endangered Native Fish and Wildlife as it appears on July 2, 1974, (Part 17 of Title 50, Code of Federal Regulations, Appendix D); and

(3) the United States' List of Endangered Foreign Fish and Wildlife (Part 17 of Title 50, Code of Federal Regulations, Appendix A), as such list may be modified hereafter; provided, that any species or subspecies of wildlife appearing on any of the foregoing lists which enters the State from another state or from a point outside the territorial limits of the United States and which is transported across the State destined for a point beyond the State may be so entered and transported without restriction in accordance with the terms of any federal permit or permit issued under the laws or regulations of another state.

(D) In the event the United States' List of Endangered Native Fish and Wildlife is modified subsequent to July 2, 1974, by additions or deletions, such modifications whether or not involving species or subspecies indigenous to the State may be accepted as binding under subsection (C) if, after the type of scientific determination described in subsection (A), the department by regulation accepts such modification for the State. Any such regulation shall be effective upon promulgation.

HISTORY: 1962 Code Section 28-729; 1974 (58) 2384; 1993 Act No. 181, Section 1264; former 1976 Code Section 50-15-40; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-40. Establishing and carrying out programs for management of nongame and endangered wildlife; removal, capture, or destruction of wildlife.

(A) The board shall establish such programs, including acquisition of land or aquatic habitat, as are deemed necessary for management of nongame and endangered wildlife. The board shall utilize all authority vested in the department to carry out the purposes of this section.

(B) In carrying out programs authorized by this section, the department may enter into agreements with federal agencies, political subdivisions of the State, or with private persons for administration and management of any area established under this section or utilized for management of nongame or endangered wildlife.

(C) The Governor shall encourage other state and federal agencies to utilize their authorities in furtherance of the purposes of this section.

(D) The department may permit the taking, possession, transportation, exportation, or shipment of species or subspecies of wildlife which appear on the state list of endangered species, or species in need of management on the United States' List of Threatened or

Endangered Native Fish and Wildlife, as amended and accepted in accordance with Section 50-15-30(D), or on the United States' List of Threatened or Endangered Foreign Fish and Wildlife, as such list may be modified hereafter, for scientific, zoological, or educational purposes, for propagation in captivity of such wildlife, or for other special purposes.

(E) Upon good cause shown, and where necessary to alleviate damage to property or to protect human health, endangered species may be removed, captured, or destroyed but only pursuant to permit issued by the department and, where possible, by or under the supervision of an agent of the department; provided, that threatened or endangered species or species in need of management may be removed, captured, or destroyed without permit by any person in emergency situations involving an immediate threat to human life. Provisions for removal, capture, or destruction of nongame wildlife for the purposes set forth above shall be set forth in regulations issued by the department pursuant to Section 50-15-20(A).

HISTORY: 1962 Code Section 28-730; 1974 (58) 2384; 1993 Act No. 181, Section 1264; 2004 Act No. 246, Section 2; 2008 Act No. 179, Section 1, eff February 19, 2008; former 1976 Code Section 50-15-50; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-50. Criteria of designating land as certified management area for endangered species; review and revision.

(A) The department shall promulgate regulations addressing criteria for designating land as certified management area for endangered species or of species in need of management in order to qualify a taxpayer for the income tax credit provided for in Section 12-6-3520.

(B) Every five years the department may review the population status of species subject to certified management agreements and shall revise the regulations accordingly. The department may revise criteria at that time as necessary for lands to retain their designation as certified management areas.

HISTORY: 1999 Act No. 100, Part II, Section 95; former 1976 Code Section 50-15-55; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-55. Omitted by 2014 Act No. 159, Section 1, eff April 14, 2014.

SECTION 50-15-60. Promulgation of regulations.

The department shall promulgate such regulations as are necessary to carry out the purposes of this article.

HISTORY: 1962 Code Section 28-731; 1974 (58) 2384; 1993 Act No. 181, Section 1264; former 1976 Code Section 50-15-70; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-65. Omitted by 2014 Act No. 159, Section 1, eff April 14, 2014.

SECTION 50-15-70. Removal of certain turtles from state; exceptions; penalties.

(A) It is unlawful for a person, or a group of individuals traveling in one vehicle, to remove, or attempt to remove from this State more than ten, either in one species or a combination of species, of the named species of turtles at one time with a maximum of twenty turtles of these species, either individually or in combination in any one year: yellowbelly turtle (Trachemys scripta), Florida cooter (Pseudemys floridana), river cooter (Pseudemys concinna), chicken turtle (Deirochelys reticularia), eastern box turtle (Terrapene carolina), eastern painted turtle (Chrysemys picta), spiny softshell turtle (Apalone spinifera), Florida softshell turtle (Apalone ferox), and common snapping turtle (Chelydra serpentina).

(B) The provisions of this section do not prohibit the sale, offer for sale, or purchase of the yellowbelly turtle (Trachemys scripta) species and the common snapping turtle (Chelydra serpentina) species if these turtles were taken from a permitted aquaculture facility or a private pond pursuant to a permit issued by the department at the request of the owner or owner's agent. Any person transporting more than ten yellowbelly turtle (Trachemys scripta) species or common snapping turtle (Chelydra serpentina) species must be in possession of a permit pursuant to which the turtles were taken or acquired and, upon request, must provide it to authorized agents of the department. A person selling, offering to sell, or purchasing these species must have documentation from the aquaculture facility as to the origin of the turtles. The department may charge twenty-five dollars for a permit.

(C) A person violating the provisions of this section is guilty of a misdemeanor and, upon conviction, must be punished by a fine of up to two hundred dollars or up to thirty days in jail, or both. A violator also must have his permit permanently revoked and may never be issued another one. Each turtle removed or in possession of a person attempting to remove them is a separate violation of this section.

HISTORY: 2009 Act No. 6, Section 1, eff May 6, 2009; former 1976 Code Section 50-15-75; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-75. Omitted by 2014 Act No. 159, Section 1, eff April 14, 2014.

SECTION 50-15-80. Penalties; searches and seizures; power to arrest; disposition of confiscated property.

(A) A person who violates Section 50-15-20 or a person who fails to procure or violates the terms of a permit issued under the regulations is guilty of a misdemeanor and, upon conviction, must be fined not more than five hundred dollars or imprisoned not more than thirty days and ordered to pay restitution.

(B) A person who violates Section 50-15-30(C) or regulations promulgated pursuant to it or a person who fails to procure or violates the terms of a permit issued pursuant to Section 50-15-40(D) and (E) is guilty of a misdemeanor and, upon conviction, must be fined one thousand dollars or imprisoned not more than one year, or both.

(C) An enforcement officer employed and authorized by the department or a police officer of the State or a municipality or county within the State may conduct searches as provided by law and execute a warrant to search for and seize equipment, business records, merchandise, or wildlife taken, used, or possessed in connection with a violation of this article. The officer or agency, without a warrant, may arrest a person who the officer or agent has probable cause to believe is violating, in his presence or view, the article or a regulation or permit provided for by it. An officer or agent who has made an arrest of a person in connection with a violation may search the person or business records at the time of arrest and seize wildlife, records, or property taken or used in connection with the violation.

(D) Equipment, merchandise, wildlife, or records seized under subsection (C) must be held by an officer or agent of the department pending disposition of court proceedings and forfeited to the State for destruction or disposition as the board considers appropriate. Before forfeiture, the board may direct the transfer of wildlife seized to a qualified zoological, educational, or scientific institution for safekeeping. The costs of the transfer are assessable to the defendant. The department may promulgate regulations to implement this subsection.

HISTORY: 1962 Code Section 28-732; 1974 (58) 2384; 1985 Act No. 25, Section 1; 1993 Act No. 181, Section 1264; 1994 Act No. 386, Section 3; 2004 Act No. 246, Section 3; 2008 Act No. 179, Section 3, eff February 19, 2008; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.

SECTION 50-15-90. Article not retroactive; certain importation not prohibited.

None of the provisions of this article shall be construed to apply retroactively or to prohibit importation into the State of wildlife which may be lawfully imported into the United States or lawfully taken or removed from another state or to prohibit entry into the State or possession, transportation, exportation, processing, sale or offer for sale, or shipment of any wildlife whose species or subspecies is deemed to be threatened with statewide extinction in this State but not in the state where originally taken if the person engaging therein demonstrates by substantial evidence that such wildlife was lawfully taken or removed from such state; provided, that this section shall not be construed to permit the possession, transportation, exportation, processing, sale or offer for sale, or shipment within this State of wildlife on the United States' List of Endangered Native Fish and Wildlife, as amended and accepted in accordance with Section 50-15-30(D), except as permitted in the proviso to Section 50-15-30(C) and Section 50-15-40(D).

HISTORY: 1962 Code Section 28-733; 1974 (58) 2384; 1993 Act No. 181, Section 1264; 2014 Act No. 159 (S.714), Section 1, eff April 14, 2014.